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Expanding Research and Development

AT the present time only two research reactors are operating in the United Kingdom outside the establishments of the Atomic Energy Authority. These are A.E.I.'s 1-5 MW swimming pool reactor, MERLIN, at Aldermaston, and Hawker Siddeley's 10-kW JASON at Langley. The first was built to provide experimental facilities for the company's staff and invitations to participate in the research programme were issued to nearby universities. Reception was somewhat cautious and few definite proposals have been forthcoming. The second was built partly as a demonstration research reactor and partly as a research facility for the company's development of reactor systems. Although no official statements have been made of the universities' requirements for research reactors, negotiations have been going on for some time and it is expected that work on at least three should begin this year. In the past, the universities have been reluctant to enter the research reactor field due partly to financial and organizational problems and partly because it was felt necessary to prepare the ground by building up experienced research teams. Also, it has proved difficult to co-ordinate the requirements of different disciplines, the nuclear engineers being the only ones to crystallize their demands.

Flux and facility requirements for physics, metallurgy, chemistry, medical and nuclear engineering research differ a good deal. It remains to be seen how long the spare capacity offered by the engineering faculties will satisfy the other faculties and how rapidly will interest in research reactors increase once the first few have been installed. One would expect them to have something of a trigger action but funds will no doubt be the limiting factor. Certainly the first round of small research reactors will not meet the demands of the country and a second round is likely to be proposed before the end of the year. Furthermore, higher powers will then be needed and it will be up to the National Institute to take a positive lead.

In many other countries around the world, interest in research reactors is growing, with a corresponding increase in the keenness of competition between manufacturers to supply demands. Although the different organizations will have different requirements in terms of power and facilities it is clear that the overriding requirement is availability and low cost. To a large extent research programmes or training courses will be moulded to fit in with facilities offered in the fully commercially developed reactors. In the past the American grants of $350,000 for a first reactor (totalling 19 excluding the special Philippines allotment) have resulted in an almost complete U.S. monopoly of the market. In many cases, however, now it is the second reactor that is being acquired, and assuming that satisfactory fuel prices can be agreed (if the fuel does not in any case come from the U.S.) British manufacturers should be able to capture a reasonable proportion of the market. This will result in greater opportunities for suppliers of British loop, irradiation, handling and measuring equipment.

A regular supply of trained research workers from the universities is of great importance to the nuclear industry as a whole. Even in the U.K. the value of sponsored research and development is on a par with the value of straight nuclear power station construction. In the past, whilst industry has contributed in no small measure to the development work, the greater part of the AEA's spending has been in manufacturing contracts with relatively little development attached. This situation is now changing and increasing opportunities are opening for industry to take over complete projects rather than act simply as suppliers of components. One of the main criticisms of the AEA's use of industry has been the limited opportunity given for overall design and for design organizations to be excluded from the overall picture, resulting in the adoption of less elegant techniques than might otherwise have been possible. Such criticism should become less and less valid as time goes on, although (to the large concerns) the burning question of whether industry should be entrusted with the development of complete reactor systems has yet to be resolved.

For the smaller manufacturer there will be greater opportunities for using latent ingenuity and specialized techniques, but this should not be interpreted as implying that profitable entry into the nuclear research and development field is easy. Past experience has shown that those concerns willing to invest their own money and their best effort in nuclear energy are the ones who will ultimately find it most worth while. Those who regard it merely as a method of employing spare or low-grade effort are almost certain to be disappointed. Experienced men will, therefore, continue to be at a premium for many years.

OEEC Energy Supply and Demand Report

THE report of the committee under the chairmanship of Professor Robinson appointed by OEEC to examine Europe's energy requirements and probable methods of meeting the demand has now been published. The recent trends in energy consumption are reviewed and forecasts are made as to the probable changes that will take place over the next 15 years.

Although the contributions to be expected from coal, oil and natural gas are expressed within reasonably narrow limits the assessment of the contribution of nuclear energy is admittedly uncertain, the maximum upper limit being expressed as 10% in 1975. For electricity production, by the same year it is suggested that the installed nuclear capacity will lie between 10,000 and 35,000 MW. In view of the United Kingdom's building programme the lower figure implies that the rest of Europe's nuclear energy industry would be still in the experimental phase. The higher figure, although modest, would on the other hand imply that nuclear techniques had become established and were beginning to take over, at least in the generating field, the work of imported fuels. The report states specifically that different members of the commission hold widely different views as to what is possible and probable.

It is no criticism of the report that such uncertainties should be definitely expressed, indeed it would have been better if in the past the three wise men, for example, had been somewhat less certain in their views.

In any event so far as the nuclear industries in the rest of Europe are concerned the position is not heartening and the recent decision of AKS to withdraw their 150-MW organic cooled reactor from the US/Euratom power demonstration programme as a result of a re-evaluation of the difference in generation cost between nuclear and conventional types over the probable life of the plant lends emphasis to this.

The cost of nuclear energy is, of course, the critical parameter. On page 95 we quote the most recent estimates of the consortia in the United Kingdom for the cost of power from Magnox reactors built in this country and abroad. In high interest areas where only single reactor plants can be accommodated 8 mill power is still some distance away but it is clear also that in the U.K., where low interest rates prevail, nuclear energy can compete on equal terms with coal and oil as soon as the plant is commissioned, and over a 20-year life may show a clear profit. Although the Robinson report considers a wide range of possible costs we suspect that it is already out of date in so far as the calculations refer to U.K. designs.

The net result is that whereas British industry can look forward to a continuing home market, the industries in other European countries must face the prospect of perhaps a 15-year investment period before regular construction contracts can be anticipated. In the light of this, a number may decide that their interests will be best served by leaving to the national and supra-national bodies the burden of continuing research and development and relying on British and American industrial experience to provide the manufacturing know-how when the need arises.

Although then, the OEEC report, which must be taken as the most authoritative now available, indicates quite clearly that there is virtually no export market in Europe in the 1960s, this may in later years prove a benefit to British industry which will continue to have unparalleled experience in the design, development and construction of nuclear plant.

CERN Accelerator Inaugurated

THE inauguration of the CERN proton synchrotron on February 5 has focused world attention on the outstanding achievement of the European Organization for Nuclear Research in bringing this vast and novel machine into successful operation. CERN first came into being on February 15, 1952, when 12 countries signed the convention setting up the interim organization. The United Kingdom remained as an observer until the convention establishing the permanent organization was signed in Paris on July 1, 1953. (Austria became the 13th member in July, 1959.)

In the meantime, work had begun on the design of a 10 GeV proton synchrotron, but following discussions with the Brookhaven team in the middle of 1952 it was decided to try out a new principle using an alternating gradient field and to aim at a beam energy of 25 GeV. Towards the end of 1953 preliminary studies were complete and recruitment of staff had begun. A great deal of research was carried out in the laboratories of the member countries and by the end of 1956 major contracts had been placed for the components of the machine.

Towards the end of November of last year protons were successfully accelerated up to 24 GeV and a few weeks later after adjustments to the magnetic field the energy was increased to 28 GeV. The intensity of the beam was measured as 10^{10} protons per pulse—significantly higher than the target figure—and equipment is already installed which should increase the beam current still further.

To have achieved the design figure was a triumph but to exceed the energy by some 25% and to be able to increase the beam current by a factor of 10 is a feat calling for the highest praise.

Many speakers at the inaugural ceremony paid tribute to Professor Bakker, the Director General, and to the Director of the Proton Synchrotron Division, Mr. J. P. Adams (designate head of the AEA's CTR Project) for whom the enterprise must rank as a great personal triumph.

DIGEST...

Surveying Significant News

Fuel Element Price Reduction

The price of Magnox fuel elements has been reduced. At current uranium prices the U.K. AEA can supply typical stacked-type elements at £17,000/tonne for British-designed, gas-cooled, graphite-moderated, reactor power stations built abroad. Changes in the market value of uranium should cause a further drop in a few years' time.

Five Ship Tenders Invited

The Government has invited tenders from five British companies for the construction of a nuclear reactor plant suitable for ship propulsion. The companies are: AEI-John Thompson (BWR), who are now linked with NPPC in the Nuclear Power Group; Babcock and Wilcox (BWR), who are associated with their American namesakes—the builders of the "Savannah" plant; Mitchell Engineering (BWR), associated with Fairfield Shipbuilding and Combustion Engineering Inc. of the U.S.; English Electric (OMR), associated with Atomics International of the U.S.; Hawker Siddeley Nuclear Power (OMR), linked with John Brown. Tenders are scheduled to be in by the middle of the year, but the Minister of Transport has made it plain that the evaluation will take a number of months and a contract for building a ship will not necessarily be forthcoming.

CEGBs New Power Stations

The Minister of Power has given his consent for a 650-MW nuclear station to be built at Sizewell in Suffolk. Tenders will now be sought with a view to construction beginning in the Autumn. Tenders for the 500-MW station at Dungeness are due and contract assessments should allow work to begin on the site in July; preliminary road works are already in hand. CEGB has also proposed a 1,000-MW station for Oldbury on the Severn, but consent to build is likely to take many months. This station is popularly expected to mark the beginning of the AGRs, but no official decision will be taken until their technical practicability can be more accurately gauged.

AKS 150-MW OMR Proposal Withdrawn

Euratom has been informed that AKS (Germany) do not propose to proceed with the erection of a 150-MW OMR as the subsidy of DM.100 million is insufficient to cover 50% of the difference between the cost of nuclear and conventional power over the expected reactor life. South West Germany is expecting to be supplied with cheap oil and the differential generating cost between nuclear and oil firing is now expected to increase with time. The withdrawal is viewed with the greatest concern by Euratom and representations are being made at the highest level to reverse the decision, otherwise the whole U.S./Euratom agreement may be jeopardized.

Garigliano Power Rating Change

SENN has approached Euratom with a request to consider jointly with the Italian Authorities the desirability of increasing the power of the Garigliano station from 150 to 230 MW. This is to be achieved by scaling the reactor rather than by installing superheat. Such a change in reactor power almost completely invalidates the comparison of costs with competitive systems undertaken by the international team set up for the purpose.

World Power Conference Sectional Meeting in Madrid

The general programme for the World Power Conference Sectional Meeting to be held in Madrid from June 5 to 9 has been issued by the Spanish National Committee. Nuclear energy will figure largely in the papers to be submitted by authorities from many countries, including the U.K. The conference has been divided into five sections: Methods of Investigation of Energy Sources and Requirements; Efficiency of Production and Utilization of Energy; Technical Developments in Transportation; Establishment of Nuclear Reactors on an Industrial Scale, Functional Interrelation between Conventional and Nuclear Production of Energy. A comprehensive tour of Spanish facilities and installations has also been arranged.

Magnox Reactor for Brazil?

Requests to tender for a Magnox station are expected by the British consortia from Brazil shortly. Brazilian authorities have been examining, during the past 18 months, the question of installing a station in their country and present indications are that the reactor will be British. Close attention has been paid to the Latina project in Italy.

Large Helium Deposits in Canada

Vast reserves of helium have been discovered in Saskatchewan in Canada and five large oil companies and a syndicate of seven smaller companies have taken out special helium permits to exploit this. This discovery is being used as a further argument against the policy of Atomic Energy of Canada, Ltd. to concentrate on heavy water reactors and at the Forum of Public Opinion of the First Canadian Conference on Uranium and Atomic Energy held in January, Winnett Boyd again called for a Royal Commission to examine Canada's policy and re-opened the question of whether it would not be more economic to invest in diffusion plant than in heavy water.

BWR Power Reactor for Puerto Rico

A contract has been signed between the U.S. AEC and the Puerto Rico Water Resources Authority for the construction of a 16.3 MW BWR which would produce nuclear superheated steam within the reactor core. The authority will provide the site and conventional facilities, operate and maintain the reactor on a reimbursable basis and purchase steam from the Commission. Estimated cost of the plant is about $11 million. This is the third nuclear superheat reactor proposed, the first being an experiment at NRTS and the second the Pathfinder project at Sioux Falls proposed by the Northern State Power Company of Minneapolis.

IAEA's Assistance to Finland

The IAEA is to assist Finland in studying the extent to which nuclear power will be needed in the country over the next decade and will recommend steps to be taken to implement any programme proposed. The Director General is negotiating with the U.S. Government on terms for the supply of the 20% enriched fuel for the TRIGA Mark II reactor bought by the Finnish Authorities and with the Soviet Government for 10% enriched fuel for their critical assembly. Both these systems are to be built at the Institute of Technology at Otaniemi.

Vickers-Armstrongs to Market General Atomics' TRIGA Reactors

Vickers-Armstrongs have signed a licence agreement with General Dynamics Corporation's General Atomics Division for the marketing of TRIGA research reactors in the U.K. The agreement covers the Mark I (below-ground model) and the Mark II (above-ground model) up to a maximum steady stage operating level of 100 kW. Vickers-Armstrongs will manufacture at their South Marston works all portions of the plant except the uranium/zirconium hydride fuel moderator elements which will be supplied by General Atomics.

Contract for Fuel Element Laboratory at Windscale

The contract for the design and provision of the £1 million irradiated fuel element cave laboratory has been awarded by the U.K. AEA to E. G. Irwin and Partners, Ltd., Consulting Engineers. The facility which is to be installed in the blower-houses of No. 2 reactor at the Windscale works will allow the examination of several thousand fuel elements a year from the generating authorities' power stations. The facility is scheduled to be completed and operating by the end of this year.

Danish PLUTO Now Critical

The 10-MW heavy-water materials testing reactor supplied by Head Wrightson Processes to the Danish Atomic Energy Commission went critical on January 17. Tests have been continuing on bringing this reactor into full commission. Head Wrightson have been awarded contracts for six reactors of this general type; PLUTO and DIDO at Harwell, DMTR at Dounreay, HIFAR in Australia, the Jülich reactor in West Germany in addition to the Danish PLUTO.

"Nuclear Engineering" Monograph Series

The latest publications (now available) in the *Nuclear Engineering* monograph series are: Nuclear Radiation Measurement and Nuclear Reactor Optimization. This brings the total published to date to nine and already in course of preparation are: Approaches to Thermonuclear Power, Nuclear Reactor Stability and Fast Reactors. These monographs have proved of great value to students and non-specialists requiring a broad understanding of those aspects of nuclear engineering outside their own immediate field of study. Editions are also published in Germany, Italy and the U.S.A.

Magnox Reactor Generation Costs

—*An up-to-date assessment*

SO much has been written in the past few months of the high cost of generating power with the present designs of gas-cooled graphite-moderated reactors using Magnox canning, and so lurid have been some of the reports of escallations on the first of the generating board's stations, coupled with the stories of company losses, that we have felt it necessary to approach all the tendering consortia in the United Kingdom, the Atomic Energy Authority and the CEGB for their comments.

At present the Generating Board is reluctant to quote a definite figure for the generating cost even for Bradwell and Berkeley, but further computation is in hand and some official statement can be expected at the World Power Conference Sectional Meeting in Madrid, if not before. It is learned that figures reputed to have emanated from the Generating Board in recent weeks were misleading and contained such additional charges as switchgear, site access facilities and excessive transmission charges which have not been added to the quoted costs of power from conventional stations. This is quite apart from the inclusion of heavy additional charges resulting from design changes.

Previously, calculations of power costs have been based upon a fuel element price of £20,000/ton. We now learn from an authoritative source that the AEA's current price for a typical stacked-type natural uranium fuel element to overseas operators of U.K. designed reactors is approximately £17,000/tonne (exclusive of packaging, but inclusive of delivery to a named British port). This figure is based upon present uranium prices and can, therefore, be expected to fall when new purchasing contracts for raw material are concluded. A maximum average figure over the life of the plant should be in the region of £15,000/tonne (assumed in the tables below) and may well be significantly less for U.K. generating authorities.

We have not attempted to analyse the process charges and credit charges for plutonium except to quote the range £5,000/£6,000 per ton overall credit including the chemical processing charge. This figure is subject to alteration and will clearly be a function of the stabilized price for plutonium, but it can be taken as representing a minimum figure rather than a maximum.

On the subject of capital cost of the plant, we invited the consortia to submit outline prices for typical 150-MW single-reactor and 500-MW two-reactor stations. It is recognized that unless the site be specified and the country of construction, such a quotation is only possible in outline terms. Nevertheless the costs given here can be taken as mean figures and not as minimum figures which assume that all conditions are favourable. The closeness of the figures of the various groups was remarkable and little difficulty has been experienced in giving average values or, alternatively, in selecting one particular group of figures as representative of them all. We quote the capital cost in terms of a British station and also of a station to be built overseas and then deduce the generation cost in terms of a low interest country such as the U.K., and where money is dear as is more generally the case abroad.

Taking the less favourable case first, Table 1 compares the generating cost of the large and small station built abroad and deduces the generating cost for fuel element prices of £20,000 per ton and £15,000 per ton. The intergrated capital charges are taken as 12% per annum and the operating load factor as 75%. The net thermal efficiency of the plant is 30% and the credit for returned fuel £5,000 per ton.

For construction in the U.K., capital charges will be slightly lower and the figures given in Table 2 are based on the assumptions shown in Table 3. In the U.K. not all the first fuel charge requires to be amortized because of the plutonium credit which will still be outstanding at the end of the life of the last charge.

We must emphasize that these figures emanate from the consortia and are based not merely upon theoretical predictions but on their experience of building this first round of Magnox reactors and with a full appreciation of the continuing research and development work necessary to support construction and operation and with a recognition that export markets cannot be relied upon to absorb any significant proportion of the initial development charges. The final figure, therefore, of 0.55d/kWh for a large generating station built in the U.K. must be recognized as being properly valid.

TABLE 1—POWER STATION BUILT IN HIGH INTEREST AREA ABROAD

Capacity	150 MW		500 MW	
Fuel element price	£20,000/t	£15,000/t	£20,000/t	£15,000/t
Cost of plant and bdgs., £/kW	140	140	100	100
Interest during constrn., £/kW	20	20	14	14
Initial fuel charge, £/kW	22	17	20	15
Total capital cost, £/kW	182	177	134	129
Total Capital charges, d/kWh	0.80	0.78	0.59	0.57
Fuel replacement, d/kWh	0.17	0.11	0.17	0.11
Operating costs, d/kWh	0.07	0.07	0.05	0.05
Generation costs, d/kWh	1.04	0.95	0.81	0.73

TABLE 2—POWER STATION BUILT IN THE U.K.

Capacity	150 MW	500 MW
Plant and building, £/kW	135	95
Equivalent capital additions (for interest during constrn.), £/kW	18	13
Extramural charges (for land, transmission, etc.), £/kW	5	5
Total capital cost excluding fuel, £/kW	158	113
Fuel investment, £/kW	16.5	16.5
Capital charges, d/kWh	0.48	0.35
Fuel investment charge*, d/kWh	0.04	0.04
Fuel consumption, d/kWh	0.10	0.10
Operation and maintenance, d/kWh	0.06	0.06
	0.68	0.55

* Calculated as 5½% of investment+2.87% of the difference between fresh fuel and the final plutonium credit (£1.5M and £4.95M).

TABLE 3—PREVAILING U.K. CONDITIONS

Interest rate	5½%
Amortization period	20 years
Capital charge	8.37%
Load factor	75%
Fuel investment	1.1 tonnes/MW
Fuel element price	£15,000/tonne
Mean fuel irradiation	3,000 MWd/tonne
Thermal efficiency	30%
Net plutonium credit (after processing)	£6,000/tonne

SAFETY PRINCIPLES for Low Power Research Reactors

By B. E. ELTHAM, B.Sc. M.I.Mech.E. (*Chief Engineer*) and E. P. HICKS, M.A. (*Senior Physicist, Reactor Safeguards Division, Health and Safety Branch, U.K. AEA*)

Growing interest in low power research reactors requires a watchful eye on safety precautions, the underlying principles being discussed in this article.

THE present interest in low-power pool and tank type reactors for university or private laboratory use makes it desirable to consider some of the safety criteria which should guide considerations of design and location. In attempting to set such standards it must be borne in mind that there is a strong economic incentive to produce a simple, reliable reactor at minimum cost and it is necessary that safety requirements are not jeopardized. In particular:—

(a) The excess reactivity in the system should be restricted to such a low value that accidental step or ramp changes do not cause a hazard;

(b) It must be guaranteed that sufficient reactor cooling is always present to avoid fuel failure or meltdown;

(c) Containment or confinement must be adequate to control any incident, without being unduly expensive;

(d) Instruments in control and safety circuits—normally the costliest plant components excluding the fuel—must not fall below some minimum quality.

This article is concerned mainly with the implications of the first three of these requirements and the related design topics. This is not to imply that instrumentation is considered unimportant. On the contrary, the safety principles underlying the choice of the instrumentation for a university reactor are of sufficient importance to merit separate detailed discussion.

Current Reactor Types

Although research reactors may be of several different types the great majority use MTR or DIDO type fuel elements, consisting of sheathed plates of highly enriched uranium, cooled by light water flowing between the plates and acting as both coolant and moderator. Graphite is used as the main reflector in a number of designs, including the AMF Atomics 10 kW tank and pool reactors, and the Hawker Siddeley JASON (a derivation of the ANL Argonaut). In one U.S. design, the ACF Industries PTR 605*, the core is water reflected. The General Dynamics TRIGA II is light water cooled and graphite reflected, but differs from the general pattern of core design by including part of the light hydrogen moderator in the fuel elements, which are made up from an alloy of enriched uranium and zirconium hydride.

The above reactors have all been built and operated at powers in the kilowatt range. Other designs, based on quite different principles, are available at powers of up to a few watts. Typical reactors of this class are the Atomics International L.77 Reactor with a homogeneous, aqueous core of uranyl sulphate solution; the Aerojet-General Nucleonics AGN 201, which has a solid homogeneous plastic core of UO_2 particles embedded in polythene, and the AGN 451, which employs a water-cooled matrix of UO_2 polythene fuel elements.

* Superseded by Allis-Chalmers' graphite reflected PTR 606.

Reactivity Limitation

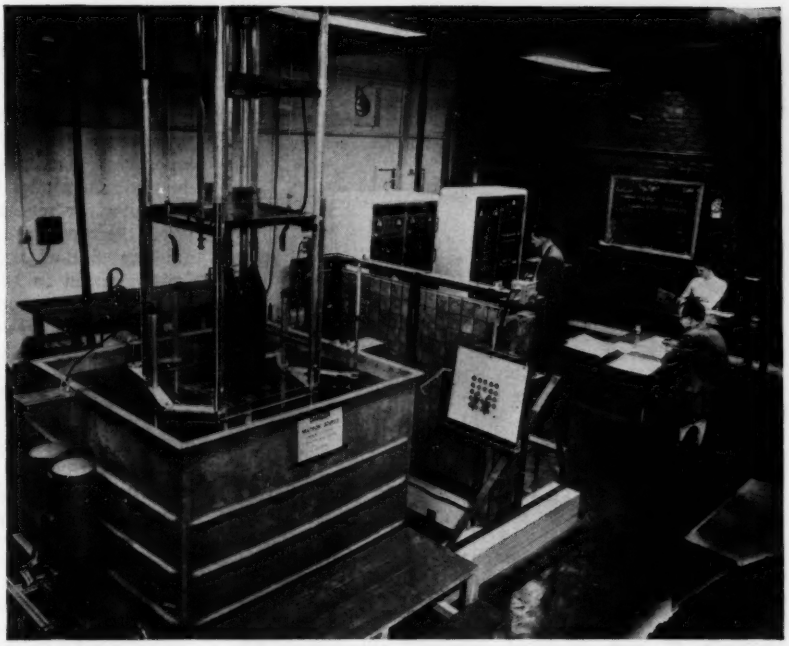
The first important safety principle for low-power research reactors required to be sited fairly freely in urban districts, is that the total excess reactivity in the core must be severely restricted. Excess reactivity can be added to the core in various ways; for example, by control rod withdrawal, by the removal of experimental absorbers from the core, by the flooding of experimental tubes, or by a change in the temperature of the coolant. In assessing the total excess reactivity all possible methods of reactivity addition are included, giving what may be defined as the excess reactivity in the core relative to the cold, clean, compact condition.

It is an essential requirement that the total excess reactivity in the core, if released in any manner, will not cause an incident severe enough to melt the fuel, with a consequential escape of fission products. This criterion will, in general, be satisfied if the total excess reactivity held in the reactor is less than the least reactivity step addition which will cause meltdown of part of the core. If this requirement is satisfied, the core may be said to be in an " eversafe " condition.

It is clearly desirable to show by direct experiment that the total excess reactivity chosen will not damage the fuel elements when added as a step change. For example, in the case of the prototype TRIGA reactor it has been shown that the system will safely withstand a step reactivity insertion of 1.6%.

In the case of light water moderated pool reactors our understanding of inherent stability and kinetic behaviour is mainly derived from the special excursion experiments which have been conducted on the BORAX-1 and SPERT-1 reactors. Analysis of the transient behaviour of SPERT-1 has shown that this type of pool reactor can be expected to withstand safely step or ramp reactivity additions of at least 1.5%. It must be noted, however, that differences exist between the core design of SPERT-1 and other reactors, the effects of which cannot at present be assessed with confidence because of our inadequate understanding of the physical processes involved. It is, therefore, considered that, for the time being, it would be prudent to limit the acceptable excess reactivity step in pool type reactors to 1% or even less. A limitation of this nature is unlikely to restrict seriously the use of the reactor as an experimental facility.

If the design is " eversafe," the only remaining possibility



The A.E.I. sub-critical facility for MERLIN—a typical example of safety in design and arrangement.

of a hazardous reactivity accident is while fuel elements are being moved to or from the core. It is clearly a sensible precaution that only one element should be moved at any one time, and this can be achieved partly by administrative action and partly by design. For example, it would be safe practice to have available only one device, capable of moving only a single fuel element.

If we now consider the reactivity which could be added to a near-critical core by the insertion of a single fuel element, and accept as a desirable principle that this should not exceed the maximum safe reactivity step, it can be shown that in some reactors, only the least reactive fuel elements, at the edges of the core, will meet this condition. In such cases strict administrative control, perhaps supplemented by limitations designed into the equipment, will be necessary to ensure that the least reactive elements are always added to the core last.

The core of an Argonaut, or similar reactor, may contain as few as 6-8 fuel elements, each of which will be worth much more than the permissible reactivity step addition. However, in reactors of this type fuel elements can be moved only with the water moderator dumped. In designs in which it is not practicable to dump the moderator, exactly the same purpose could be served by a large shutdown absorber.

It is, of course, essential to ensure that these safety features cannot be circumvented. In addition to administrative control, it would seem desirable to incorporate design features and interlocks which prevent access to the core unless the moderator has been dumped or the shutdown absorbers inserted.

Whenever fuel is added, replaced or re-arranged in the core, the possibility always exists that too much fuel has been added, so that the core is no longer eversafe when the moderator is replaced or when the shutdown absorbers are withdrawn. It is therefore important that, following an occasion in which the core is modified, the first subsequent approach to criticality should be made under carefully controlled conditions, in which measured and predicted count rates are compared at a series of points along the start-up curve.

When a fuel element is added to the core, the design may be such that partial insertion into the lattice goes undetected, leaving the possibility that the fuel element may later fall into the fully inserted position and release an excessive step change of reactivity. It is considered essential that such a possibility be obviated by means of positive indications on all charging or loading machines in order to ensure that fuel (and reflector) elements are fully home, and that they should then be locked into position to prevent possible accidental displacement at a later date. In small reactors this requirement could be met easily by locating a locking plate over the core.

Heat Removal

A low-power research reactor can be cooled either by a forced-circulation primary circuit giving up heat to an external heat exchanger, or by a free-convection primary circuit which transfers heat from the core to the bulk water, together with, perhaps, a cooling coil. The essential requirement to be imposed on the design is that, if any or all of the forced cooling flow ceases, and the safety circuits fail to shut the reactor down, the reactor would continue to operate safely for a considerable time—at least a few hours. It is, in general, a simple matter to demonstrate that this condition can be met if the operating power is only 10 kW, and it can probably be satisfied without difficulty at 100 kW.

The other coolant accident condition which needs consideration is that of complete loss of coolant water. Many low-powered research reactors incorporate facilities for deliberately dumping the light water coolant-moderator. In others, the possibility exists of an accidental loss of coolant, for example, as a result of a pipe failure while the reactor is shut down and unattended overnight. It is therefore an essential design requirement that the core can safely absorb or dissipate the decay heat after full-power operation in the event of complete loss of water from the reactor tank. In practice there is no likelihood of fuel elements melting and releasing fission product after operation at 10 kW. The consequences following operation at 100 kW would require careful study against a particular reactor design.

In addition to the thermal consequences of loss of coolant water, there may also be a direct radiation hazard from the loss of the shielding provided by the pool. This will be most significant for designs in which the water provides the whole or most of the top shielding, and its magnitude must be checked for any particular reactor and its location. Consideration will need to be given to the problems arising in core unloading, and it may prove

One of the safety arrangements on the MERLIN sub-critical facility; fuel storage rack with lock on each individual element.

necessary, at least, to make provision for appropriate emergency action.

Damage from External Sources

There is also the possibility of damage to the core from an external accident. The most plausible course of events that could introduce a serious hazard would appear to be a fire spreading in some way from the reactor building to the core. Clearly, the reactor shielding constitutes an important fire barrier, and the chance of any external conventional fire causing melting of the fuel would seem exceedingly remote. It is necessary to emphasize the need for adequate fire precautions throughout the reactor building, particularly with respect to materials of construction. For all normal reactor installations the existing building and fire regulations are adequate.

Reactor Control

Although the problems of reactor control are not particularly difficult in a properly designed low-power research reactor, it is useful to attempt to lay down acceptable criteria. As with all reactors, the first essential requirement is that the negative reactivity invested in the control system must be greater than the total excess reactivity in the core in order to shut the reactor down in any circumstance. The safety rods are a source of additional negative reactivity to allow for contingencies; for example, partial failure of the control system.

In the particular case of low-power research reactors with limited invested reactivity, the second desirable principle is that the negative reactivity invested in the control system should be no more than is necessary to control the reactor. This limitation helps to ensure that the reactor is not operated with more than the permitted excess reactivity and minimizes the consequences of accidental uncontrolled withdrawal of the control rods. A third essential is that sufficient negative reactivity must be inserted into the core at shutdown to make the core adequately sub-critical while fuel is being moved; the requirement is that the core should remain safely sub-critical even after the addition of one complete fuel element to a nominally complete core. This requirement, together with an adequate approach-to-critical procedure, provides a satisfactory safeguard against fuel-loading accidents.

If the same absorbers are used for both control and shutdown, there is clearly a conflict between the second and third requirements, and the third must override the second. However, it is frequently possible to meet both requirements by separating the functions of control and shutdown. For example, in reactors of the Argonaut type, more than adequate negative reactivity is inserted by dumping the moderator on shutdown. With other designs, particularly when the worth of a fuel element is rather large, there would appear to be safety merit in the use of a special shut-off rod or similar absorbing device which is fully inserted in the core at shutdown and completely removed during the start-up procedure.

It is desirable, in principle, that the negative reactivity invested in control and safety should be shared among the largest practicable number of elements, each controlling a minimum of reactivity. In the case of a low-power reactor with small invested reactivity, a minimum of three control and safety rods (one fine control, one coarse control and one safety) would normally be considered acceptable. However, if the total excess reactivity in the core does not exceed 0.5%, a single control rod controlling say about 0.7% negative reactivity would appear unexceptionable.

Containment

Although it is considered that a major release of fission products from a sensibly designed low-power research reactor is not credible, our experience in the operation of such equipment is still slight, and it is prudent to provide a margin of safety, both by containment and by siting.

In attempting to prescribe the degree of containment required it should be noted that the release of activity from even the most extreme forms of core failure is mitigated by the characteristics of the release. When solid fuel elements melt, substantial fractions of gaseous and volatile fission products are released, but only a very small fraction of the solids.

The dominant hazard to the surrounding population in this type of release arises from radioactive iodine; other elements, in particular strontium, are relatively unimportant. The primary danger arises from the inhalation of iodine as the plume passes overhead, and the limiting criterion in any siting consideration is the emergency dose of 25 rem to a child's thyroid. Hazards arising from the ingestion of contaminated vegetables and milk will be less important for the typical urban sites of university reactors and, in any case, the release which might be expected from any credible accident is so small that it can be readily controlled.

The possible risk of a minor release of activity has suggested that the factors of safety involved in the overall design of the installation can be considerably enhanced by the provision of a relatively simple and inexpensive type of building. The specification for such an enclosure is, in general terms, that it should be adequately fire-resistant and reasonably gas-tight, and should be of sound construction with simple arrangements for sealing openings, such as doors and ventilation holes, in any emergency. The use of window glass which might be fractured in any incident is not recommended.

Conclusions

It is clear from the above discussion that the hazards involved in the operation of small low-powered research reactors are small, and that the system should be capable of being operated in complete safety providing attention is paid to certain basic principles. Of these, the most important relate to the need to restrict the excess reactivity to an eversafe amount and to ensure that adequate cooling is inherent in the core design.

RESEARCH REACTORS

A Survey of Current Designs, Part 1

Babcock Open Pool 1-5 MW

THE Babcock and Wilcox open pool research reactor is designed for from 1-5 MW operation. It comprises essentially a pool of demineralized water spanned by a movable bridge from which is suspended an aluminium grid or indexing plate. Sufficient clad aluminium-uranium alloy fuel elements for the required reactivity are assembled on this plate. The elements, which are manufactured by B. and W., can be easily loaded or unloaded manually from the bridge. The company is presently supplying both highly enriched and 20% enriched fuel elements for research reactors located in the U.S. and many countries throughout the world.

Experimental facilities include 6-in. and 8-in. radial beam ports, a 6-in. or 8-in. through tube, a pneumatic tube system, either a fixed position wall-mounted or a movable water immersed graphite thermal column, and fuel element-size irradiation sample holders. The instrumentation and safety systems are flexible and adaptable. Control and safety shutdown of the reactor is accomplished by four movable control rods. These are one stainless regulating rod and three cadmium-lined, boron-carbide safety rods. If an unsafe condition is approached, magnets release the safety rods automatically and allow the rods to fall into the core. The regulating rod may be positioned manually or automatically to maintain reactor power at the desired level independent of small reactivity changes.

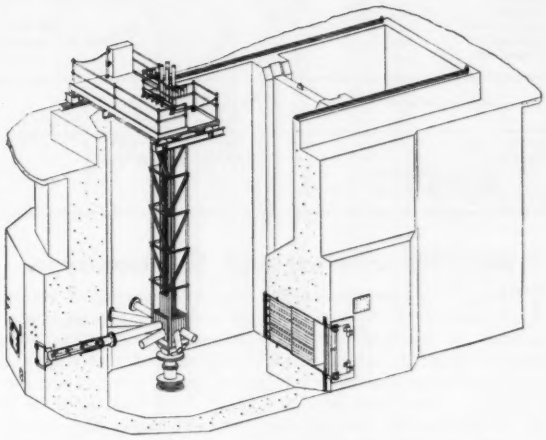
The Babcock and Wilcox Company has had extensive experience as designers and fabricators of pressure vessels, heat exchangers, and piping for all ranges of temperature and pressure, in both nuclear and conventional applications. This experience is reflected in the design and construction of the primary system equipment. The company is working on a heterogeneous reactor system for transient power pulsing capable of approximately 10^{17} neutrons/pulse. The unit will be sold either as a separate facility or as a complement to an existing pool reactor, thereby increasing the usefulness and experimental flexibility of the pool concept.

The reactor is sold through Babcock's extensive sales network. The company has an agreement with Babcock and Wilcox, Ltd., of London, to share nuclear information.

(The Babcock and Wilcox Company, Atomic Energy Division, 161 East 42nd Street, New York 17, N.Y.)

Company	THE BABCOCK AND WILCOX COMPANY
Designation	None
Type	Open pool reactor
Application	Teaching, research and isotope production
No. installed and Critical	(3) Ford Nuclear Reactor, Ann Arbor, Michigan, 1 MW; Institute de Energia Atomica, Sao Paulo, Brazil, 5 MW; Kernenergie, Hamburg, Germany, 5 MW.
No. on order	(1) Camen, Leghorn, Italy, 5 MW
Basic price	Approx. $300,000 to approx. $700,000 (depending on facilities required).
Power rating	1–5 MW
Fuel enrichment	20% or above 90%
Fuel element type	Parallel plate
Element dimensions	3 in. × 3 in. × 34½ in. (approx.)
Core loading (element No.)	Variable
Core loading (wt. U-235)	Variable (depending on enrichment and weight per cent) (generally 3–4 kg).
Moderator	H_2O
Reflector	H_2O and/or Graphite
Coolant	H_2O
Coolant flow	Downward with forced circulation above 200 kW, upward with natural circulation below 200 kW.
Shielding	H_2O and concrete
Overall size	Approx. 12 ft wide, 28 ft high, and 40 ft long

Hole and beam facilities	Thermal flux at 5 MW	Fast flux at 5 MW	Gamma flux
10 to 12	$2–4 \times 10^{13}$ n/cm² sec. (at core edge)	$4–8 \times 10^{13}$ n/cm² sec. (at core edge)	8×10^{4} (at outside 8 in. beamhole)



Babcock and Wilcox open pool research reactor with a wall mounted thermal column.

Indatom's Pool Reactors

INDATOM have constructed three swimming pool reactors for the Commissariat de l'Energie Atomique: MELUSINE (rated at 1.2 MW and located at Grenoble), TRITON (similar to MELUSINE but located at Fontenay-aux-Roses) and MINERVE (also at Fontenay, but rated at 100 W). As a result of experience gained the company has designed two pool reactors which are simpler and cheaper. They are known as AMELIE and BEATRICE.

The core bridge has been omitted in both reactors, the core resting on an easily movable support. As with TRITON the primary cooling circuit is immersed in the pool. Control rod drives are immersed and integral with the rods.

AMELIE is an underground pool reactor. The intention was to design a reactor as simple and as practical as possible for a very reasonable price. The reactor does not have any beam tubes; access is made according to the present tendency in France from above and through the water.

The tank is watertight and of a light alloy. This fully welded and X-rayed tank is built with the greatest possible precautions. It is self-carrying. Before the pouring of the concrete, the tank is filled with water to test its tightness. It has a volume of 103m³. The decay holdup tank (14m³) is placed under the core. The tank is held by a concrete block, from which it is isolated by "isodrite."

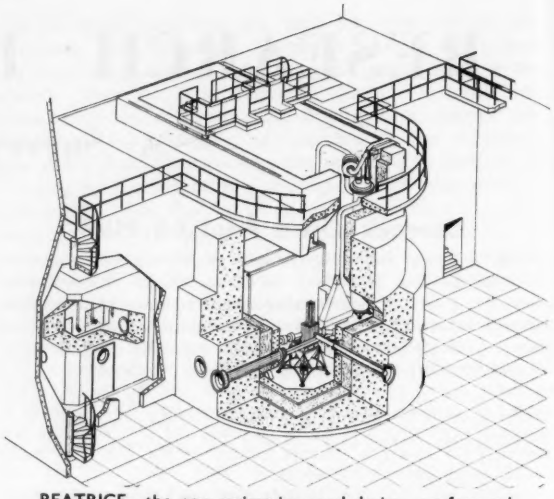
BEATRICE is a standard pool reactor with two compartments and four radial beam tubes with a diameter of 150 mm and a tangential of 100 x 100 mm. The radial tubes can be disassembled from the top of the pool, they are designed to bring out the neutron beams, but irradiation tubes could be installed.

The pool is a tank of prestressed concrete, rendered watertight. Additional protection is furnished through ordinary concrete. The inner lining is of varnished tiles, jointed with "Duroscite" putty on an Araldite base.

A simple wall of 4·75 m separates the two compartments. The water is sufficiently high to let the fuel elements pass from one compartment to the other and to store the core in one compartment, while the other is empty.

Company	INDATOM
Designation	Amelie and Beatrice
Type	Swimming pool
Application	Research
No. installed	—
No. on order	—
Basic price	On application
Power rating	1.3 MW
Fuel enrichment	20% U-235
Fuel element type	MTR 12 plates
Element dimensions	80×76×873 mm (overall)
Core loading (element No.)	25 elements
Core loading (wt. U-235)	approx. 4 kg
Moderator	light water
Reflector	Graphite or light water
Coolant	—
Coolant flow	200 m³/hr
Shielding	water and concrete
Overall size	—

Hole and beam facilities	Thermal flux	Fast flux
Amelie : none	$<10^{13}$ n/cm² sec	$< 10^{14}$ n/cm² sec
Beatrice: (4) 150 mm radial beam. (2) compartments.		



BEATRICE—the new swimming pool design put forward by Indatom of France.

Atomics International Solution-type

THE aqueous homogeneous, or solution-type, research reactor developed by Atomics International is of special interest because of its inherent safety characteristics. The large negative temperature and power coefficients of reactivity provide an effective shutdown mechanism in the event of a power excursion. Fuel costs are minimized, and fuel additions in any predetermined amounts can be easily and safely made. Versatile experimental facilities can be inexpensively provided, including high-level gamma ray exposure facilities which are essentially free of neutrons. This type of reactor has a relatively low cost; a small operating staff is adequate to maintain the reactor with complete safety.

The solution-type research reactors placed in operation by Atomics International during the past several years fall into three power-range categories. The largest is the L-54. Designed to operate at 50 kW it has the advantages of a large graphite reflector, both horizontal and vertical thermal columns, and gamma exposure facilities in its sub-pile area. An intermediate range reactor, designated the L-55, has been designed to operate at power levels up to 1.5 kW. Its most unique feature is a large vertical column, 5½ feet square, which is especially useful for experimental work of the exponential type. The most compact unit, designated the L-77, is designed to operate at 10 watts and is intended primarily as a training facility.

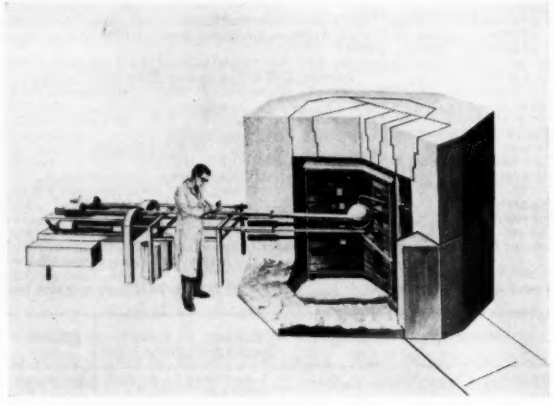
Despite the large variation in operating power, these reactors have several features in common. All three operate with a water solution of uranyl sulphate fuel. Sulphate is preferred to nitrate because of greater radiation stability and smaller parasitic neutron absorption; higher uranium concentrations are possible.

The original L-8 reactor was designed and built for the Armour Research Foundation in Chicago, Illinois. It was installed and started up in 1956 and was then authorized to operate at 10 kW. Subsequently power levels of up to 100 kW have been authorized.

At about the time the Armour reactor was completed, a second reactor was being designed for the Japan Atomic Energy Research Institute. It was apparent that modifications would be necessary due to the limitation of using 20% enriched uranium fuel. This revised design became known as the L-54 reactor. The Japan L-54, or JRR-1, was installed and first operated in the summer of 1957. It has been operated at a maximum power level of 62 kW. Similar reactor installations have been completed and are now in successful operation in Europe. (*Atomics International, P.O. Box 309, Canoga Park, California.*)

Company	ATOMICS INTERNATIONAL (Division of North American Aviation, Inc.)
Designation	L-8, L-54, L-55, L-77
Type	All solution type
Application	Research and training
No. installed	L-54, four; L-8, one; L-55, one; L-77, two
No. on order	One L-54 for Walter Reed Army Medical Center, Washington, D.C.
Basic price	Approx. $100,000 (L-77) to $300,000 (L-8, L-54)
Power rating	L-77, 10 W; L-55, 2 kW; L-8 and L-54, 50 kW
Fuel enrichment	L-54, L-55, L-77, 20 to 90%; L-8, 90%
Fuel element type	All homogeneous, uranyl sulphate
Element dimensions, core size	L-54, L-77, 15½ in.; L-8, L-55, 12½ in. dia.
Core loading element No.	—
Core loading (wt. U-235)	L-8, L-54, L-77, all 1.1 to 1.4 kg; L-55, 1 kg
Moderator	All water
Reflector	L-77, lead and organic; L-8, L-54, L-55, graphite
Coolant	L-77, none; L-8, L-54, L-55, water
Coolant flow	L-77, none; L-8, L-54, up to 15 g/m; L-55, 3 g/m
Shielding	L-77, boron, lead, water; L-8, L-54, L-55, all concrete
Overall size	L-77, 8 ft by 8 ft; L-8, L-54, 15 ft by 18 ft by 11 ft (above floor level); L-55, 15 ft by 15 ft by 10 ft (above floor level)

Hole and beam facilities	Thermal flux (max.)	Fast flux (max.)	Gamma flux
L-8 (3) 10.1 cm horiz.	1.4×10^{12} n/cm² sec.	2×10^{12} n/cm² sec.	—
L-54 (2) 7.16 cm horiz. (4) 10.1 cm vert. (1) 5.1 cm pneu. straight (1) 3.8 cm pneu. curved (1) 3.8 cent. expos. (1) horiz. thermal (2) 15.2 cm dia access ports (2) 15.2 cm sq. access ports (1) vert. col. 1.37 m dia	1.52 m. sq. ×1.60 m.		
L-77 (1) 3.48 cm exposure (4) 1.9 cm exposure (2) 4.75 cm beam (2) 7 cm spare inst. thimble (1) 0.38 cm gas tube	2.2×10^{8} n/cm² sec.	6.8×10^{8} n/cm² sec.	—
L-55 (1) 1 in. exposure (4) 4 in. dia through holes (1) 5.5 ft square thermal col.	5×10^{10} n/cm² sec.	8×10^{10} n/cm² sec.	—



The 2 kW solution-type L-55 by Atomics International.

General Atomic's TRIGAs

THE TRIGA reactor was conceived, designed and built by the General Atomic Division of General Dynamics Corporation. The prototype reactor, in San Diego, has been in operation for approximately one year and has been operated at power levels up to 1.4 MW. The reactor is presently undergoing a series of transient tests involving the step insertion of large amounts of excess reactivity. To date, 3.0%Δk/k has been inserted in the reactor, yielding a maximum transient power level of 2,000 MW. While these experiments were being performed, personnel were in the immediate vicinity of the reactor tank. The integrated dose at the surface of the water was less than 20 mr. There has been no sign of reactor instability, void formation, or expulsion of water from the core. The first year's operation of the prototype has been accomplished with no changes in system reactivity, changes in the reactor temperature coefficient, contamination of the reactor water, or significant radiation dosage to personnel. The integrated generation for the prototype reactor is now 30 MWh.

TRIGA is available in two forms: Mk 1, the original design, is below ground, whilst Mk 2 is entirely above ground. Of the reactors sold so far five are Mk 1s and 10 are Mk 2s. The core utilizes an entirely new type of fuel element developed by General Atomic. In the solid fuel element, zirconium-hydride moderator is homogeneously combined with 20% enriched uranium. A unique feature of these fuel elements is a prompt negative temperature coefficient which automatically limits the reactor power to a safe level in the event of a power excursion.

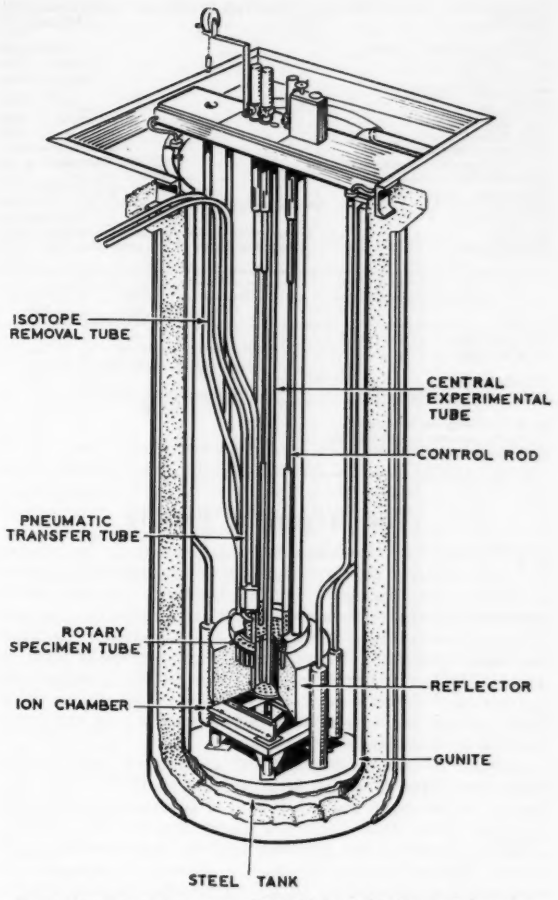
The TRIGA Mk 2 has versatile student training research and isotope production facilities. A large thermal column with removable graphite stringers provides a source of well-thermalized neutrons. The radial beam tubes are placed for convenient performance of a variety of experiments, such as neutron diffraction and time-of-flight studies. A rotary specimen rack is located in a well in the top of the graphite reflector for the production of radioisotopes in useful quantities. Extremely short-lived radioisotopes can be produced and rapidly conveyed from the reactor to a counting room by the pneumatic transfer facility for conducting a variety of experiments and for the irradiation of a small sample at the point of maximum flux. Full visual and physical access to the core during reactor operation is possible through the vertical water column. In addition, extra experimental positions may also be added by lowering containers or dry tubes through the water column to the core region.

So far all sales of both TRIGA models have been handled by General Atomics. Last month, however, the company concluded an agreement whereby Vickers-Armstrongs will manufacture these reactors in the U.K. *(General Atomic Division, General Dynamics Corporation, P.O. Box 608, San Diego 12, California.)*

Company	**GENERAL ATOMICS (Division of General Dynamics Corporation)**
Designation	TRIGA Mk. 1 and Mk. 2
Type	Pool-type
Application	Training, research, isotope production
No. installed	14
No. on order	1
Basic price	Less than £100,000
Power rating	Up to 100 kW (steady state)
Fuel enrichment	20% U-235
Fuel element type	Solid homogeneous alloy of uranium and a zirconium hydride moderator
Element dimensions	—
Core loading (element No.)	—
Core loading (wt. U-235)	2.2 kg
Moderator	8% wt uranium; 91% wt zirconium; 1% wt hydrogen
Reflector	Graphite, aluminium clad
Coolant	Water
Coolant flow	Primary, natural; secondary, chiller or heat exchanger
Shielding	16 ft water over core; Mk. 1, earth; Mk. 2, 7.5 ft concrete
Overall size	Mk. 2, 26 ft×21.5 ft×21 ft high

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
Mk. 1: rotary specimen rack, pneumatic transfer tube, central thimble	1.6×10^{13} n/cm² sec. at 100 kW	—	—

Mk. 2 has in addition: (4) 6 in. beam, (1) Thermal column 4 ft×4 ft×5.5 ft, (1) Bulk shielding facility 9 ft×8 ft×12 ft.



The below-ground version of TRIGA built by General Atomics.

Foster Wheeler Tank-type

THE Foster Wheeler Tank-type research reactor has been designed for reactor training, a wide range of research experiments, engineering test work, and radioisotope production.

The reactor makes available neutron fluxes of the order of 10^{13} to 10^{14} n/cm² sec for a power level of 1-5 MW. Beam holes of up to 13 in. diameter may be provided which will permit large objects to be inserted up to the reactor core face. For studying short-lived activities, objects of up to 1 in. diameter can be sent within seconds through pneumatic tubes into the reactor and from there to the experimental floor.

The reactor comprises a cylindrical, water-filled aluminium tank near the bottom of which is located a support grid on which fuel elements and reflector elements are assembled. The support grid accommodates various geometrical configurations of fuel and reflector elements: the particular arrangement depends on the type of experiments which are in progress at any particular time. The fuel element is of the MTR-type capable of using 20% enriched, as well as fully-enriched uranium. The reaction is controlled by poison rods positioned by actuators located on the tank-top cover. The water in the tank acts as a moderator, coolant, and partial shield. It is circulated down through the reactor assembly, through a hold-up tank and heat exchanger and is returned to the tank by a pump.

Both reactors supplied—a 1 MW LPTR to the U.S. AEC and a 5 MW RD2 for Risø, Denmark—are now in operation. Foster Wheeler research reactors are sold through the company's own sales offices. The U.K. subsidiary is Foster Wheeler Ltd., 3 Ixworth Place, London, S.W.3.

(Foster Wheeler Corporation, 165 Broadway, New York 6, N.Y.)

Company	FOSTER WHEELER CORPORATION
Designation	LPTR and DR2
Type	Tank
Application	Research
No. installed	Two
No. on order	None
Basic price	—
Power rating	5 MW
Fuel enrichment	90%
Fuel element type	MTR
Element dimensions	3 in. × 3½ in. × 24½ in.
Core loading (No. of elements)	22 std; 5 shim safety rods
Core loading (wt. U–235)	4.6 kg
Moderator	H_2O demineralized
Reflector	Canned graphite on sides H_2O at top and bottom
Coolant flow	1,500 gal./min.
Shielding	Dense concrete barytes or magnetite and water
Overall size	Octagonal block 19.5 ft across flats 26.5 ft high

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
(1) 13 in. beam	—	—	—
(5) 6 in. beam	4×10^{13} n/cm² sec.	8×10^{13} n/cm² sec.	—
(2) 4 in. beam	—	—	—
(1) 2 in. horiz. through tube	1 foot from thermal column 10^9 n/cm² sec.		—
(6) 4 in. irradiation facilities	—	—	—
(2) 1½ in. pneumatic tube facilities	—	—	—
(1) Thermal col. 4 ft × 4 ft	—	—	—

The Argonaut Family

DESIGNED by Argonne National Laboratory for training and research, the Argonaut is now available in a number of forms. It is marketed by two American and one British company. The basic assembly comprises a graphite cube with a central annular core formed from two aluminium tanks. In the centre there is a removable cylindrical graphite reflector. The MTR fuel elements are mounted in the annulus with waterproofed graphite segments between them. Water circulated through the core annulus acts not only as a moderator but also as a coolant.

In spite of the disadvantage of a relatively large critical mass, the Argonaut has a large volume available for experiments. A feature of the unit is ease of construction the shielding being either stacked concrete blocks or monolithic concrete.

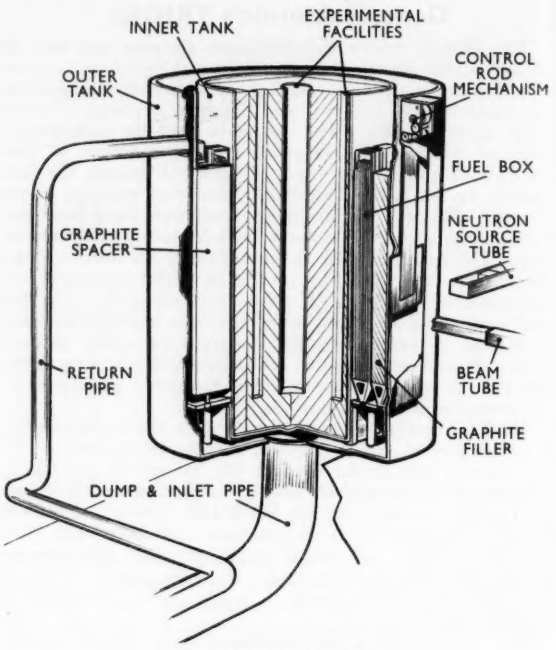
In the version of the Argonaut sold by American-Standard's Atomic Energy Division, the annular geometry is replaced by a fixed two-slab arrangement with a rectangular graphite reflector between. Each tank is sub-divided into six fuel chambers and the critical mass loading is of the order of 3 kg.

A two-slab core arrangement is also a feature of the AMF Atomics-General Nuclear Engineering Educator. The graphite section measures 5 ft square by 9 ft and contains six aluminium fuel boxes arranged in two rows. The boxes contain 24 fuel-element bundles.

Finally, there is JASON, the British-built version of Argonaut, marketed by Hawker Siddeley. The annular core arrangement is retained but DIDO-type fuel element assemblies are used in one of three possible configurations, the critical mass varying from 2 kg to 4.2 kg depending on the arrangement selected.

Company	HAWKER SIDDELEY NUCLEAR POWER CO., LTD.
Designation	JASON
Type	Argonaut
Application	Research
No. installed	1
No. on order	1
Basic price	£50,000
Power rating	10 kW (cont.)
Fuel enrichment	20 to 90%
Fuel element type	DIDO plates
Element dimensions	—
Core loading (element No.)	—
Core loading (wt. U–235)	2 to 4 kg
Moderator	H_2O and graphite
Reflector	Graphite
Coolant	H_2O
Coolant flow	—
Shielding	Concrete
Overall size	—

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
Thermal column with 14 ports	1.5×10^{11} n/cm² sec	—	—
Int. col. (5 ports)		—	—
(2) beam tubes		—	—
Shield tank		—	—



Core of 10 kW JASON.

Company	AMF ATOMICS—G.N.E.
Designation	Educator
Type	Argonaut
Application	Research
No. installed	—
No. on order	—
Basic price	$175,000
Power rating	10 kW
Fuel enrichment	20%
Fuel element type	MTR plates
Element dimensions	—
Core loading (element No.)	—
Core loading (wt. U–235)	4 kg
Moderator	H_2O and graphite
Reflector	Graphite
Coolant	H_2O
Coolant flow	—
Shielding	Concrete
Overall size	—

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
Thermal col, 6 ports:			
(3) vert. beam tubes	—	—	—
(6) horiz. beam tubes	—	—	—
shield tank/beam tube	—	—	—
(16) vert. foil slots	—	—	—

Company	AMERICAN STANDARD
Designation	UTR 10
Type	Argonaut
Application	Research
No. installed	—
No. on order	—
Basic price	$175,000
Power rating	10 kW
Fuel enrichment	20 to 90%
Fuel element type	MTR plates
Element dimensions	—
Core loading (element No.)	—
Core loading (wt. U–235)	3 kg
Moderator	H_2O
Reflector	Graphite
Coolant	H_2O
Coolant flow	—
Shielding	Concrete
Overall size	—

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
Thermal col, 15 ports; Int. col. 5 ports:			
(2) beam tubes	—	—	—
Shield tank	—	—	—

Aerojet-General Range

A WIDE range of low-power reactors is offered by Aerojet-General Nucleonics. The smaller units have an ingenious fuel element comprising 10-20 micron UO_2 particles homogeneously dispersed in polyethylene. Internal heat transfer takes place in negligible time and resultant heating of the polyethylene causes negative reactivity in two ways. Increased average thermal energy of the neutrons causes a prompt decrease in reactivity due to Doppler broadening of the U-238 resonance and consequent greater parasitic absorption of neutrons. Simultaneously, the prompt expansion of the fuel elements decreases the moderator density thereby increasing the leakage of neutrons. In the event of an excursion, the reactor is promptly shut down by inherent physical properties independent of electronic and mechanical controls.

Company	AEROJET-GENERAL NUCLEONICS
Designation	AGN 201, AGN 201M, AGN 201P
Type	Tank
Application	Educational and isotope production
No. installed	AGN 201, 11; AGN 201M, 2; AGN 201P, 1
No. on order	AGN 201, 1
Basic price	AGN 201, $95,000; AGN 201P, $112,000
Power rating	0.1 W (with shielding up to 20 W)
Fuel enrichment	20% UO_2
Fuel element type	10–20 micron UO_2 particles in polyethylene
Element dimensions	—
Core loading (element No.)	—
Core loading (wt. U–235)	Approx. 650g
Moderator	Polyethylene
Reflector	20 cm graphite
Coolant	Water
Coolant flow	—
Shielding	10 cm lead, 56 cm H_2O
Overall size	2 m×3 m

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
(1) 2.35 cm horiz. (4) 10 cm expos. ports (1) Water tank 81 cm dia×58 cm deep.. (1) Graphite thermal col. 81 cm×58 cm deep	4.5×10^8 n/cm² sec. at 100 mW	—	—

Model 201 rated at 0.1 W nominal has the lowest critical mass of any production reactor—656 g of 20% enriched U-235—and therefore comprises a most useful device for student training. Model 201P is similar but has a higher flux requiring more shielding and is capable of operating at 20 W continuously (peaking at 1 kW for 2.5 min/h).

Company	AEROJET-GENERAL NUCLEONICS
Designation	AGN 211; AGN 211P
Type	Pool
Application	Educational
No. installed	AGN 211, 2; AGN 211P, 2
No. on order	—
Basic price	AGN 211, $95,000; AGN 211P, $116,567
Power rating	15 watts (up to 1 kW with extra shielding)
Fuel enrichment	20% UO_2
Fuel element type	UO_2 dispersion in polyethylene
Element dimensions	—
Core loading (element No.)	—
Core loading (wt. U–235)	Approx. 785g
Moderator	Polyethylene
Reflector	30 graphite elements each 7.3×7.8×61 cm
Coolant	Water
Coolant flow	—
Shielding	Concrete 1 m thick, 2.3 m high
Overall size	2×3×3.4 m

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
(1) 2.5 cm verts. (1) Bulk irradiation Optional graphite thermal cols, horiz. hole, beam tubes exposure ports.	5.5×10^8 n/cm² sec. at 15 W	—	—

The next AGN models are the 211 and 211P. Here the design changes from a tank to a pool, the normal operating level of the 211 being 1 W with a peak thermal flux of 3.7×10^7 n/cm² sec and the 211P being rated at 100 W with a peak thermal flux of 3.7×10^9 n/cm² sec. Extra shielding is required for the 211P because of the higher flux.

The AGN 401 is a tank-type unit rated at 10 kW. Although designed for educational work this reactor provides ample flux for the production of short-lived isotopes. The 451 pool-type operates at levels of up to 100 kW and is available in three

Company	AEROJET-GENERAL NUCLEONICS
Designation	AGN 401 / AGN 451
Type	Tank / Pool
Application	Research, isotope production
No. installed	—
No. on order	— / 1
Basic price	$138,000 and upwards
Power rating	10 kW / Up to 100 kW
Fuel enrichment	20% U–235
Fuel element type	Plate / MTR 18 plates
Element dimensions	7.6×7.6×61 cm
Core loading (element No.)	20
Core loading (wt. U–235)	2.5 kg / Approx. 3.5 kg
Moderator	H_2O
Reflector	Graphite, polythene.. / Graphite and H_2O
Coolant	H_2O
Coolant flow	—
Shielding	lead, concrete / 4.2 m water above and concrete
Overall size	6.7 m×7.3 m

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
(1) 2.5 cm holes graphite thermal col. 10 and 15 cm beam tubes, 2.5 cm pneu. rabbit.	10^{12} n/cm² sec at 100 kW	—	—

forms: below ground, above ground and horizontal. The largest AGN model is the ANTR (Aerojet Nuclear Testing Reactor) providing fluxes of up to 3×10^{14} n/cm² sec at 10 MW. This reactor was designed specifically for materials testing. The company claims that the cost is less than one-tenth that of an MTR-type. *(Aerojet-General Nucleonics, P.O. Box 77, San Ramon, California.)*

Company	AEROJET-GENERAL NUCLEONICS
Designation	ANTR
Type	Open pool
Application	Materials testing
No. installed	—
No. on order	—
Basic price	—
Power rating	10 MW
Fuel enrichment	90% or 20%
Fuel element type	Plate type; assemblies of 18 elements
Element dimensions	—
Core loading (element No.)	16 assemblies
Core loading (wt. U–235)	90% approx. 3,150g; 20% approx. 3,600g
Moderator	H_2O
Reflector	Beryllium
Coolant	Light water
Coolant flow	30,000 l/m
Shielding	Concrete
Overall size	—

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
10 cm centre in-pile loop (4) 7 cm reflector loops.. (18) Capsule irrad. spaces, bulk neutron irrad., gamma irrad, etc.	3×10^{14} n/cm² sec	—	8×10^6 r/h

NDA 10 kW D_2O-type

THE TRR (Teaching and Research Reactor) is a nominal 10 kW machine with an operational capability of 25 kW. The reactor is heavy water moderated, reflected, and cooled; additional reflection is provided by graphite and Masonite; fuel is fully enriched uranium in the form of aluminium clad uranium-aluminium alloy plates; the heavy water is contained in an aluminium tank; shielding is ordinary concrete; a D_2O-to-H_2O heat exchanger is incorporated. Horizontal irradiation and/or beam ports and vertical thimbles are provided in the graphite reflector for experimental purposes. The reactor is designed for use in a ground-level room. No shielding is provided beneath the reactor.

The TRR makes available, through the use of heavy water as moderator and coolant, a teaching tool with a high degree of inherent safety. Isolation of the experimental access facilities from the core reduces the reactivity effect of experiments on the core and on each other. The low neutron absorption of heavy water permits this isolation with only small sacrifice in flux. The design of the basic unit facilitates the inclusion of additional experimental facilities such as additional thimbles and beam ports. A thermal column or bulk shielding facility may also be included as well as a central thimble penetrating to the core region. *(Nuclear Development Corporation of America, 5 New Street, White Plains, N.Y.)*

Company	NUCLEAR DEVELOPMENT CORPORATION OF AMERICA
Designation	TRR
Type	D_2O tank
Application	Teaching Research Reactor
No. installed	—
No. on order	—
Basic price	—
Power rating	10 kW (nom); 25 kW (steady state)
Fuel enrichment	—
Fuel element type	MTR-type
Element dimensions	—
Core loading (element No.)	40
Core loading (wt. U–235)	Approx. 700g
Moderator	D_2O
Reflector	D_2O, 1 ft graphite, 3 in. Masonite
Coolant	Primary, D_2O; secondary, H_2O
Coolant flow	—
Shielding	½ in. borated plastic, concrete
Overall size	—

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
(2) 6-in. horiz. beam (1) 6-in. horiz. beam with resonance tube (1) 4 in. × 4 in. × 3 ft horiz. stringer (4) 1¼-in. vert. thimbles	4×10^{11} max n/cm² sec.	—	—

Allis-Chalmers High Flux Reactors

TO meet research and educational needs, the Massachusetts Institute of Technology required a reactor that would be safe enough to be built on the MIT campus and still provide fluxes high enough to support an extensive programme in neutron diffraction, neutron beam therapy, exponential experiments, and basic irradiation experiments. Specifically, the MIT irradiation programme required a high flux in the experimental facilities without excessive reactor-power levels; the possibility of increasing the fast flux in selected ports; and a medical facility with a high thermal and low fast flux, and a low gamma dose rate. On the basis of these requirements, A-C established the working design of the Massachusetts Institute of Technology Reactor (MITR), and constructed the reactor and buildings. The reactor first went critical in July, 1958, and has been operated at normal operating power levels without mishap since September, 1959.

The MITR is a 1 MW heterogeneous reactor, cooled and moderated by heavy water, and reflected by heavy water and graphite. At full power, the maximum thermal flux in the experimental facilities is 1.2 x 10^{13} n/cm² sec; in the medical therapy facility the thermal flux is 10^{10} n/cm² sec, the fast flux is only 10^{7} n/cm² sec, and the gamma dose rate is 100 r/h. The fuel is an alloy of fully enriched uranium and aluminium in the form of curved plates.

To permit the fast flux to be increased in selected ports, there are eleven extra fuel positions outside the 19-element primary fuel array. Fuel elements in these peripheral positions behave as fission-plate converters, and make it possible to bring the region of highest flux to the end of any of several beam ports.

A graphite thermal column extends from the core to within 30 in. of the face of the biological shield. A remotely operated 6-in.-thick lead shutter at the inner end of the thermal column reduces the gamma dose from the graphite to acceptable levels so that the thermal column can be opened during shutdown. The thermal column is penetrated by three large ports in front, one in the top and one on either side. If it is necessary, an irradiation cave can be formed in the outer end of the thermal column. The medical therapy facility beneath the reactor is used by several medical research teams in the Boston area. A large port beneath the core admits a neutron beam down into the medical facility. The port is closed by a shutter consisting of an H_2O tank and a composite boron and bismuth shutter. When the H_2O tank is filled, it moderates and absorbs most neutrons from the core. When the H_2O is pumped out and the boron part of the shutter is slid back to admit neutrons into the medical facility, enough bismuth remains to reduce the gamma intensity to an acceptable level. The MITR also incorporates thirteen beam ports, one through port, eight instrument ports, four rabbit facilities, six vertical thimbles into the graphite from the top of the reactor, and up to ten small sample thimbles at the core edge in the extra fuel positions. The spent-fuel storage tank is used as a gamma facility.

Company	THE ALLIS-CHALMERS MFG. COMPANY
Customer	Massachusetts Institute of Technology
Designation	MIT Reactor
Type	Heavy water CP–5 type
Application	Basic research
No. installed	One
No. on order	—
Basic price	—
Power rating	1,000 kW
Fuel enrichment	90% U–235
Fuel element type	Aluminium plate (MTR type)
Element dimensions	3½ in. × 3½ in. × 24 in. long
Core loading (element No.)	19
Core loading (wt. U–235)	2.2 kg
Moderator	D_2O
Reflector	Graphite
Coolant	D_2O
Coolant flow	700 gal/min
Shielding	66 in. magnetite-steel concrete (280 lb/ft³)
Overall size	20 ft across hexagon faces, 15 ft high

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
(6) 4 in. radial (4) 6 in. radial (1) 12 in. radial (2) 6 in. rotary (1) 6 in. through (8) 4 in. instr.	1.2×10^{13}	See *footnote*	
(4) Pneumatic tube	—	—	—
(10) In core, 1 in.	1.5×10^{13}	3×10^{13}	—
(6) 3 in. vertical	—	—	—
(1) Thermal column	5×10^{12}	—	—
(1) Medical therapy	10^{10}	10^{7}	100 r/h

Footnote: The fluxes given in this tabulation are subject to confirmation.

For the Reactor Centrum Nederland (RCN), Allis-Chalmers are supplying a 20-MW heterogeneous reactor based on the ORR design. This reactor is cooled and moderated by ordinary water and produces a maximum fast-neutron flux of 7.3×10^{14} n/cm² sec and a maximum thermal-neutron flux of 2.3×10^{14} n/cm² sec.

The reactor core is housed in a tank which is immersed in a pool of water, and experimental facilities of various sizes extend from the pool walls to the tank. There are eight 6-in. and two 10-in. horizontal beam tubes, which extend up to two faces of the core. Each beam tube is equipped with an electrically operated lead shutter. A large experimental facility hole, approximately 5 ft in diameter, permits large experiments to be placed close to the core and may be converted to a thermal column without rearranging the core or the other experimental facilities. Since the control rods are driven by mechanisms beneath the core, small experiments may be inserted through the top of the reactor tank into any of the 81 fuel or reflector spaces; larger in-core experiments may be placed so as not to interfere with fuel handling operations. Experiments with short-lived isotopes may be performed with four rabbit facilities; large shielding studies and engineering tests may be conducted in the pool at the face of the reactor tank. *(The Allis-Chalmers Mfg. Co. Nuclear Power Dept., Washington, D.C.)*

Company	THE ALLIS-CHALMERS MFG. COMPANY
Customer	Reactor Centrum Nederland
Designation	RCN High-Flux Reactor
Type	Light water tank (ORR) type
Application	Materials testing and research reactor
No. installed	One
No. on order	—
Basic price	—
Power rating	20 MW (t)
Fuel enrichment	90% U–235
Fuel element type	19 curved plate MTR type
Element dimensions	3.186 in. × 3.032 in. × 36¾ in. long
Core loading (element No.)	29 standard plus 6 control rod fuel followers
Core loading (wt. U–235)	4.3 kg
Moderator	Demineralized H_2O
Reflector	Beryllium with H_2O in blanket tank
Coolant	Demineralized H_2O
Coolant flow	11,600 gal/min through core
Shielding	H_2O and magnetite concrete
Overall size	32 ft across flats; 10 sided arrangement; 28½ ft high

Hole and beam facilities	Thermal flux	Fast flux	Gamma flux
(2) 10 in. horiz. beam tubes (8) 6 in. horiz. beam tubes (1) Thermal column (3) Hydraulic rabbit facilities (1) Pneumatic rabbit facility (1) Channel for 8 in. vertical facility		See *footnote*	

Footnote : These fluxes will be the subject of experimental determination when the reactor has operated at full power.

RESEARCH REACTORS

—*the Universities' Approach*

1 By Professor W. B. HALL, B.Sc.(Eng.), A.M.I.Mech.E. (*University of Manchester*)

TWO main functions of a university reactor are training in nuclear engineering, and experimental work in a variety of fields such as reactor physics and engineering, chemistry, metallurgy, and medicine. Before considering the choice of reactor, it is worth mentioning the type of work which can be envisaged in these two categories. More weight has been given to nuclear engineering as this is the author's main interest; however, the requirements of other workers, notably radio-chemists, have been taken into account in so far as they are known at this stage of developments.

Training in Nuclear Engineering

At the present time it is by no means easy for the young engineer or physicist entering the nuclear power industry to gain first-hand experience in the operation of a reactor, or the experimental techniques associated with it. The best he can expect is to be associated with an operating team, where interesting demonstrations of the characteristics of the system for his benefit will certainly not be encouraged, or with a research team whose work will probably be restricted to a rather narrow aspect of reactor technology. This situation can be overcome to a certain extent in the case of the operating engineer by the use of a reactor analogue; indeed, there are cases where the analogue is more suitable for this purpose than a particular reactor, as its characteristics are more readily changed. It remains, however, a theoretical exercise and cannot be said to replace practical experience with a reactor. In the case of the potential research worker in reactor technology, there is no substitute for a reactor if he is to be given a broad grounding in experimental techniques.

Typical examples of experiments which would form part of a reactor training course for post-graduate engineering and physics students are as follows:—

(1) Approach to criticality; determination of critical size and control rod worth.
(2) Control rod calibration.
(3) Measurement of flux distributions.
(4) Temperature coefficient measurements.
(5) Demonstration of control characteristics.
(6) Absorption cross section measurements; "danger coefficient" and oscillator techniques.

Experimental Projects

It would be difficult to justify the provision of a university reactor on the same basis as, for example, an experimental reactor operated by the Atomic Energy Authority. A university could not make available the staff and resources to contribute greatly to the volume of experimental data which is currently being obtained by the Authority; in fact, it would be quite wrong to attempt to do so. There are, however, many problems which, although they may not be immediately relevant to the current nuclear power programme, are, nevertheless, of considerable academic interest. There are also cases where experiments in an industrial organization fall short of a detailed understanding of the problem, although they are perfectly satisfactory for normal design purposes. Finally, experimental techniques, such as those required in the detailed measurement of neutron flux and energy spectrum, might constitute a useful field for university research.

The bulk of the nuclear engineering experimental work will use the reactor as a source of neutrons for sub-critical assemblies. For many such experiments a flux of about 10^5 neutrons/cm^2 sec at the face of the thermal column is adequate, although for measurement of the finer detail of the neutron flux in some lattices, a flux of 10^7 or 10^8 may be required.

The Choice of Reactor

As a reactor is, by university standards, a fairly expensive piece of equipment, it should be capable of serving a range of interests within the university. Most of the interest outside nuclear engineering arises in radio-chemistry; a maximum thermal neutron flux of about 10^{11} appears to cover most of the requirements. The majority of reactor physics experiments, particularly those using the reactor as a neutron source for sub-critical assemblies, do not require a flux as high as this. The maximum flux, therefore, should be at least 10^{11}, and higher levels up to about 5×10^{11} for limited periods might be investigated, provided they do not greatly increase the cost of the scheme.

Safety in operation can be built into the reactor, as is well demonstrated by the TRIGA design. The close thermal coupling of the fuel and the zirconium hydride moderator ensures a prompt negative temperature coefficient; it is stated that the control rods can safely be withdrawn with the normal loading of fuel in the core. A water moderated system, provided it is under-moderated, exhibits a similar, if smaller, degree of safety. Both of these designs would thus be suitable.

A graphite reflector and preferably two large (4 ft by 4 ft) thermal columns should be provided, and will be used either for driving exponential or fine structure stacks or for irradiation work in the lower flux range ($\sim 10^8$—10^{10}). A vertical thermal column directly above the core is a further advantage as it can be used for exponential measurements along the axis of a liquid moderated assembly. At least one of the beam ports should pass right through the shield (tangential to the core) so that experimental loops can be accommodated.

As far as the configuration of the core is concerned the main choice appears to lie between cylindrical or annular. The critical mass of the latter design (e.g., the JASON type of reactor) will be greater, and it will, therefore, incur higher fuel fabrication and hire charges. On the other hand, it provides a considerable irradiation space in the internal reflector at a flux close to the maximum. There is also the possibility of placing experimental lattices in this internal space and making the complete assembly critical. In order that the spectrum at the centre of such an assembly shall be representative of its lattice and not of the reactor, such experiments are probably limited to hydrogenous systems with a small lattice pitch.

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Finally, perhaps the most important aspect of a design for a university reactor is its flexibility. Whatever the present interests in the reactor as a research tool, one can be sure that in a few years' time they will have changed. Every effort should be made to ensure that unnecessary induced activity in structural materials is avoided, so that once the fuel has been removed it will be possible to carry out modifications to the reactor. A sectional biological shield in units of a size that can be handled by the overhead crane seems worth while for the same reason.

Criteria Governing the Choice of a Research Reactor for South Africa

2

By **Professor J. P. F. SELLSCHOP***
(Director, Nuclear Physics Research Unit, University of the Witwatersrand, Johannesburg, South Africa)

THE consideration of the desirable properties of a research reactor presupposes a decision on the desirability for the country in acquiring a reactor at all. In many ways the factors which justify the acquisition of a research reactor determine what its properties should be. Let us consider, therefore, whether South Africa should follow the example of many other smaller countries in acquiring, by purchase or construction, such a device.

There can be no doubt that the resources of South Africa, in the form of funds, scientific and technical manpower, are limited. On November 12, 1959, the Research Director of the Atomic Energy Board announced that he had at his disposal for an initial five-year period the sum of £761,000 per annum, and that he anticipated further contributions would increase this to £800,000 per annum. One should remember that these funds would have to bear the cost of a complete programme, of which a reactor would form but a part, even if it were the central part. The immediate deduction is at least that South Africa cannot justify the acquisition of a reactor solely on the hope that, once acquired, it would be used.

South Africa can, however, justly be proud of the standard and vigour of its universities, of the activities of the South African Council for Scientific and Industrial Research, and of the strength of its industries. There is no doubt that these bodies are acutely aware of the impact of atomic energy on the world, and are desirous of participating in some way. To these considerations it should be added that the Union of South Africa is a major producer of uranium, and, as such, fills a very relevant rôle in the world picture. It stands very greatly to the credit of the mining groups that in a relatively short space of time the uranium extraction industry has so effectively established itself. In view of the efforts made by the industry, the country should assure that the industry can continue to prosper. Considering the "general recession in atomic energy," of which Sir John Cockcroft is recently reported to have spoken in Geneva, this last requirement will be difficult to meet, but is not any the less vital.

If this summary of the South African position is accepted, it would seem that any programme of activities in which a research reactor might be justified should encompass as its major aims:—

(a) To assist the uranium industry in producing, so far as this is practicable, its products in the form the consumers require them, and at competitive prices;

(b) To assist the universities in their teaching function, including as a sine qua non thereby assistance in their research activities, for the training and development of the scientists essential to the success of any programme or industry;

(c) To exploit the existing potential of all the national laboratories;

(d) To prepare, on a long-term basis, for the possibility of the ultimate use of atomic energy in South Africa; and

(e) To enable those scientists whose interests lie more in the fields fundamental to atomic energy rather than in the exploitation of atomic energy as such, to make a real contribution on international standards in these fields.

There can be no doubt that without a research reactor such a programme cannot be started. It is also obvious that the most important criteria for selection are imposed by the extent to which it is thought wise to embark on a fuels and materials programme. It is perhaps unfortunate, in view of the economic and manpower restrictions in South Africa, that for an effective materials programme a reactor of high average flux, say 10^{14} n/cm^2 sec, with many holes, is required. The experience of those major establishments with such reactors indicates a basic capital, running cost and manpower investment beyond the limits of the existing resources for this field in South Africa.

One solution to this impasse would be to use major facilities abroad—on some established basis of co-operation—for those costly parts of the programme that demand the highest fluxes, thereby benefiting directly from the enormous manpower and financial investment made by the owners of such a reactor. This would result in a limitation on the criteria imposed on the choice of a research reactor for use in South Africa.

Returning now to the fields where the highest fluxes are not required, the most obvious property to be demanded of a reactor placed in South Africa would be versatility. It is desirable that it should serve the engineer, the metallurgist, the chemist and the physicist. One might hope for it to have one loop experiment, while being suitable also for other functions, of which bulk shielding tests, oscillator experiments, radiation damage studies, production of isotopes, and neutron scattering are some examples.

For service to such a variety of demands, accessibility is an obvious requirement. One would hope for this to be true also to enable modest experiments on core design to be executed.

A more obvious criterion is its suitability as a training facility. This brings with it the demands that it be inherently safe, and that only a few staff should be required for running and maintenance. Of great importance is the fact that the less expensive it is to run, the more of the

* The author wishes it to be quite clear that the comment and views expressed here are his own in a completely personal capacity. The Atomic Energy Board of the Union of South Africa has recently announced a research and development programme—the author's remarks are not in any way intended to be read in conjunction with the Board's programme.

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available capital and manpower become free to exploit the device.

Finally, a less direct demand, but of considerable importance for a country such as South Africa, is that of the long-term usefulness of the chosen reactor. One should attempt to get a reactor with features which, with imaginative application, might allow unique work to be done. An example is that of being able to pulse a reactor of quite modest steady state performance to remarkable high fluxes. It is this type of feature which could be exploited with great promise.

It is not possible to simply list the desirable properties of a research reactor as relevant to a particular country. The consideration of the demands that would be imposed on any reactor that would be installed in the Union of South Africa does at least outline some essential features.

Undergraduate and Post-Graduate Requirements

3

By **Professor W. MURGATROYD, M.A., Ph.D.**
(Queen Mary College, University of London)

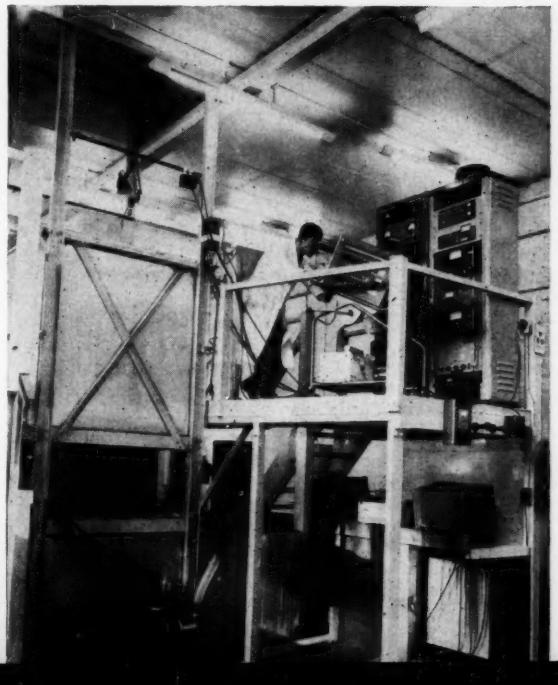
THE nuclear engineering laboratory of Queen Mary College is primarily concerned with post-graduate work. Undergraduate activities are restricted to providing third year engineers with an optional course on the fundamentals of reactor nucleonics. A course of experiments is given to supplement the lectures. Simple and relatively inexpensive equipment is adequate for undergraduate work of this nature. For example, the principles of neutron diffusion, with absorption and multiplication can be studied using tanks of appropriate liquids. Such experiments are simple and, as they are safe and do not require elaborate experimental techniques or data processing, they can be carried out independently by students in the short time available. A nuclear reactor would be of very limited value in a course of this nature.

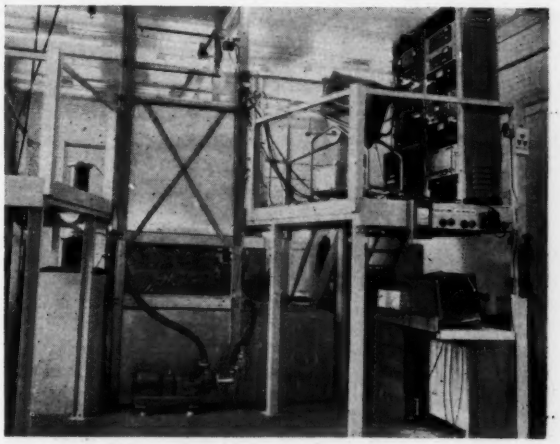
A reactor requires a trained and competent operator and undergraduates would, therefore, not be permitted to operate it. Moreover the type of experiment for which a reactor is necessary involves a more detailed theoretical background and more experimental time than undergraduates are likely to possess. If, however, a reactor were freely available close at hand, undergraduates would certainly benefit. By being present during a start-up or during fuel removal operation, for example, they would learn much about the atmosphere of nuclear engineering.

In the post-graduate field, experience has shown that it is difficult and undesirable to separate advanced courses and research. If the courses are to be of real post-graduate standing they must be presented by staff who are experienced and enthusiastic enough to encourage and assist students in developing individual interests. Normally these conditions can only exist in research groups. This is particularly true in nuclear engineering where familiarity with the research point of view is extremely important.

Three of the four research groups in the laboratory are concerned directly with reactors; the reactor nucleonics, kinetics and heat transfer groups. In the reactor nucleonics laboratory research is being carried out on the behaviour of neutrons in reactor lattices. The present phase of the work, supported by the Department of Scientific and Industrial Research, is concentrated on water moderated systems, using pulsed and steady neutron sources. A pulsed source is available but, if the work is to develop, a fairly intense source of well thermalized neutrons will be needed—the immediate requirement is for an isotropic thermal flux of at least 10^8 n/cm^2 sec over an area of some 20 ft.^{2}, and fluxes ten times as high as this might be needed later. A careful study of different ways of providing such a flux has shown that by far the cheapest and most satisfactory neutron source would be a low-powered nuclear reactor.

The reactor kinetics group is concerned with the





The present sub-critical assembly at Queen Mary College can be activated either by an isotope source or a pulsed accelerator source of neutrons.

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applications of numerical transform calculus and of statistical methods to predicting and controlling reactor behaviour. The theoretical work so far carried out indicates that to use these powerful techniques effectively, new kinds of experimental data are required from reactor cores. It is not clear to what extent such data can be obtained from sub-critical assemblies, and in determining this, a reactor would be an invaluable tool, both as source of neutrons and as a critical assembly.

The post-graduate courses which are at present being given last one year and centre on the nucleonic behaviour of the reactor core. In these courses it is important that the students should appreciate the usefulness and the limitations of simple theories, and the judicious blend of theory, experiment and experience which is the essence of engineering progress. Experimental work forms an important part of the courses and the students, having learned the basic techniques during the early part of the year, are expected to undertake projects lasting up to six months. Experience in the United States has shown the great value to such a course of a low power reactor. A number of instructive pre-arranged experiments can be safely carried out on the reactor itself. In addition it can enable realistic shielding experiments to be performed, as well as providing an endless source of student projects.

About three years ago it became apparent that the laboratory might eventually need a low power reactor. Studies of the probable requirements and of the type of reactor most suited to them were therefore commenced. At that time it seemed likely that it would be necessary to design a reactor, but as commercial designs of proven reliability and safety began to appear, it seemed more expedient to modify one of them to suit. The pool type of reactor was carefully considered. It has certain advantages and many variants of it have been constructed. In some of them the water acts as coolant, moderator and shield, while in others a separate moderator is provided. The current research programme, however, would require both vertical and horizontal thermal columns and it is difficult to provide an efficient vertical thermal column from a pool type reactor. The laboratory has, therefore, considered the extent to which the JASON reactor could be modified. A vertical bare face or thermal column could easily be provided if the top plug of JASON were replaced by one of lead or bismuth, to act as a gamma shield. The horizontal thermal column is also available and the opposite face can be used either for a graphite-moderated lattice or as a bare face for shielding experiments. The graphite reflector is advantageous as it provides a larger area of neutrons at the bare face than a water reflector.

To own and operate a reactor is a major undertaking for a university, particularly in view of the organization needed to ensure safe and effective utilization. Flexibility in the system is therefore important so that future requirements can be met with the minimum cost and inconvenience. From this point of view the JASON type, with its removable shielding blocks, is favourable since the foreseeable demands of the nuclear engineers could be met from three of the five available faces, leaving two faces for future needs.

Experience with a 1MW Research Reactor Facility

4 By Professor H. MAIER LEIBNITZ
(Director, Laboratorium fur Technische Physik der Technischen Hochschule, Munchen)

THE research reactor of Technische Hochschule München, an engineering college with about 6,000 students, was installed to help in the training of physics students, of whom there are about 120 per year, through post-graduate research work. It was also meant for studies in radiochemistry and, as the reactor was to be the first in Germany, some applied work was expected in connection with industry and with other reactor projects. The reactor is also open for work by other scientists, from both Technische Hochschule and outside institutions.

The reactor, a 1-MeV swimming pool type, has been in operation for two years; most of the research projects are well under way, and it has proved quite adequate for the projects envisaged when it was planned.

Beam Tube Facilities

There are six horizontal beam tubes, all of which are used to bring beams out of the reactor shield. One serves a large neutron diffraction apparatus for crystal structure studies; another is connected with a crystal monochromator for neutrons of thermal and slightly higher energy. There is also a mechanical velocity selector for sub-thermal neutrons. These last two are used mostly in studying binding effects in neutron scattering, and they are generally useful in separating slow neutrons from the gamma and fast neutron background, which is quite troublesome in a light water-moderated reactor. One tube holds, near the reactor, a thin foil of enriched uranium; fast fission products are deflected and focused by a magnet system outside the field. Three more tubes are used to bring out beams of reactor neutrons with various degrees of collimation. Most beam tubes are 6 in. dia., but often it is not necessary to use the full opening near the reactor. All tubes can be evacuated, which seems to be useful for the reduction of background or the elimination of gas activity. One thing we should like is a large recess in the outer shield around each beam tube to get equipment nearer the reactor and to make shielding easier.

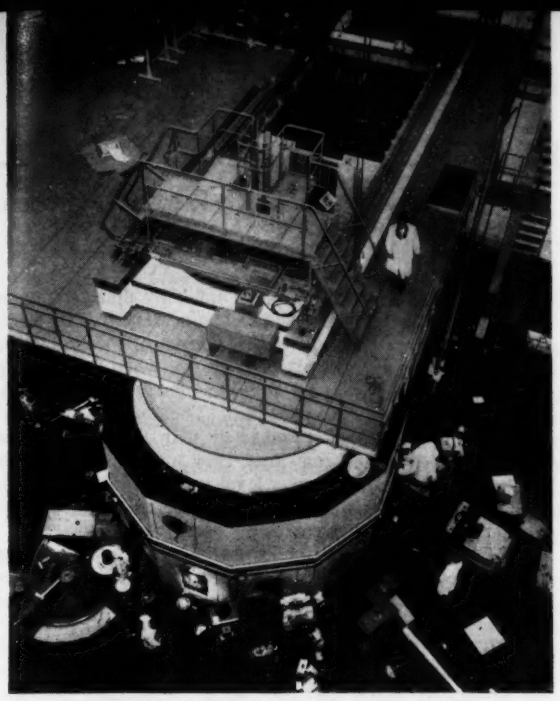
There are two more beam tube openings sloping downwards towards the reactor, ending on platforms above the main floor. One is a tangential tube and will bring out radiations from a target in the tube, the other will be used for a fast rabbit system.

Irradiations

All samples for irradiation are inserted into the pool from above, in plastic, quartz, or aluminium capsules. Irradiation space is near the reactor sides, or within special fuel elements with openings like the ones used for control rods. A four-tube rabbit system with air cooling will be installed shortly because handling of samples after irradiation in the pool water is somewhat lengthy.

Loops and Special Equipment

So far, all loop experiments are operated from above. There is a second moving bridge over the pool for experiments, and a moving gridplate near the reactor. Special



The 1 MW swimming pool reactor at Munich, which first went critical on October 30, 1957, has six horizontal beam tubes.

equipment, e.g. a pile oscillator, is operated in fixed positions near the reactor, also from above. Aluminium-canned graphite elements can be used as a reflector at one side of the reactor to increase the thermal to fast neutron ratio. A low-temperature cryostat for irradiation near the reactor is being planned.

Space around the reactor begins to be crowded but there have been no difficulties. The flexibility of the pool type reactor with easy access using equipment of various shapes is greatly appreciated. Also, we feel very strongly that the flux in our reactor (about 10^{13}/cm² sec in the centre for fast and slow neutrons) is necessary for most experiments (except for radiochemical work), and is, on the other hand, small enough to avoid excessive difficulties in cooling and handling equipment near the reactor. Also, with about 2% total installed excess reactivity and with four control rods, we have had no reactivity problem in operation.

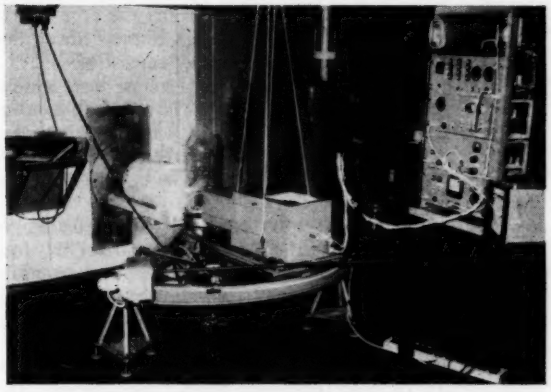
The reactor hall is 30 m in diameter, with the reactor slightly off centre. This dimension appears both adequate and necessary. The overhead crane covers a diameter of 20 m. Its clearance above the pool is equal to the pool depth, which is greatly useful in all loop-type experiments.

The reactor is operated only in the beam tube position, and at full power most of the time. The operational staff for day and night operation (which is not yet done) constitutes, roughly, the following (without administration, general services, and research staff):—

Director of operations and deputy	2
Chief Supervisor, Supervisors, and Operators ...	12
Maintenance, including electronics	4
Beam tube service	2
Irradiation service	2
Loop experiment service	2
Health physics	8
Chemistry	3

A small hot laboratory belongs to the reactor station. It is quite necessary for work on samples after irradiation before they are used in experiments. A cryogenics laboratory on the site (liquid hydrogen and helium) is extremely useful, and is expanding rapidly.

The reactor installation as described can carry research projects for more than 100 scientists at one time. Part of this work is carried out on the site, and part in the main laboratory in the town. The cost of operation, including experiments, is considerable. Our experience is not far from the empirical rule, valid for any large project in science, that the total expense per annum does not decrease after the buildings and the installations have been erected.



Bent crystal gamma ray spectrometer.

Melusine—the Swimming Pool Reactor of the Reactor Centre in Grenoble

5

By **F. ROSSILLON**
(Reactor Division Head of the Atomic Energy Centre in Grenoble)
M. SOUTIF
(Professor at the University, Head of the Nuclear Engineering Department)

THE swimming pool reactor MELUSINE of the Atomic Energy Centre of Grenoble started operation on March 13, 1959, construction having begun in May, 1957. At the nominal power level of 1,200 kW, the maximum thermal flux is 1.2×10^{13} neutrons/cm² sec; the maximum flux of uncollided fission neutrons is 1.7×10^{13} n/cm² sec and the maximum gamma ray dose, 5×10^{8} r/h. The MTR-type fuel elements are arranged on a 56-hole grid plate, hanging from a bridge, as is the practice in most swimming pool reactors.

In normal operation, the reactor works for 125 hours a week without interruption. In seven months it has given a total output of 95 MWd.

The experimental facilities consist of:—

(1) Thirty-one holes arranged over two faces of the core, when the grid plate is loaded with 25 fuel elements.

(2) Four horizontal beam tubes 6 in. in diameter and one tangential 4 in. square beam tube. These are located on the other two faces of the core.

(3) A compressed CO_2 actuated pneumatic transfer tube, 1½ in. in diameter.

(4) A hot cell adjoining a compartment of the pool, that

RESEARCH REACTORS—the Universities' Approach

is used for the taking to pieces, and the repair of the experimental devices.

These can be introduced either under water through an air-water lock 9 in. in diameter, 80 in. long, or in lead shielding, when the discharge coffins of the horizontal tubes are employed. The operation can also be performed remotely by means of the overhead crane which can travel from the swimming pool area to the hot cell area through an opening in the roof of the latter.

In Grenoble, the operators greatly prefer having access to the core through the water from above. This avoids the lengthy and expensive manufacture of plugs necessary for the horizontal beam tubes.

Grid Plate Holes

Use of the grid plate holes nearest to the core is very convenient for in-pile experiments. Indeed, the space available in the vicinity of the core is of great importance; the fluxes in this region are high and experimental facilities are easy to build. Also, the shielding (being water) around the facility takes up its position automatically, whatever its shape. Thus, it is possible to set against the core five or six specimen containers or loops even if their absorption factors are high. A typical bank may consist of:

(a) A specimen holder containing nickel or iron samples to be irradiated in a magnetic field. The aim is to measure the magnetic perturbations induced by the fast neutrons. A magnetic field of 2,500 oersteds is created by a solenoid consisting of thin aluminium oxidized wire, directly cooled by the water of the reactor.

(b) A liquid nitrogen loop used for the irradiation of materials at low temperature. Commissioning of this loop was made difficult by the formation of ozone under heavy gamma irradiation, resulting from oxygen traces in the liquid nitrogen. These problems have now been overcome and the loop is fully operational.

(c) A loop working at room temperature allowing the manufacture of high polymers from diisobutylen. This loop is provided with the equipment required for the separation of the polymers and the in-pile recycling of the starting material. The whole has been running continuously for the past eight months.

(d) An irradiation loop for organic materials at temperatures higher than 400°C. The construction of the loop is being completed presently. It will be put into the reactor during the first quarter of this year.

(e) A specimen container for the measurement under irradiation of the hydrogen absorption in stainless steel wires brought to a high temperature by electric heating.

Swimming Pool Irradiations

MELUSINE is not used for shielding experiments (in France, this function is fulfilled by the reactor TRITON). The swimming pool is, however, used for bulk-irradiation tests of materials for which doses of irradiation of the order of 10^5-10^6 r/h are required.

Beam Tubes

The beam tubes are much less " booked " by the research laboratories of the centre than the grid holes. However, the beam tubes are used amongst other things for:

Neutron diffraction experiments carried out with an automatic spectrometer working day and night.

Magnetic electronic resonance investigation of lattice defects and free radicals with a facility now being installed. The equipment is designed to enable the study of the resonance to be made during irradiation and over a temperature range from 4°K to room temperature.

A cell for the irradiation of graphite at high temperature in a hydrogen atmosphere.

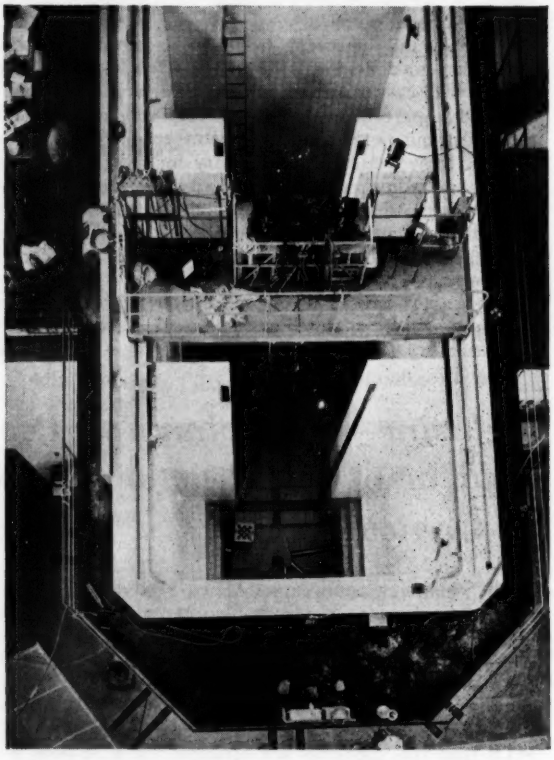
Nuclear Engineering Course

Experiments are carried out at times by undergraduates attending the course of nuclear engineering in Grenoble. They are of two types. The first consist of measurements at a low flux level, generally carried out when the burn-up of the fuel is such that an addition of new fuel elements, or a change of some, is required. The students take part in all the measurements connected with the restarting of the reactor. At the same time, they make measurements of the flux distribution, power level and control rod calibration. This work is, however, hampered by the high background of gamma radiation.

The second type comprises experiments made during normal operation. These are mostly neutron and gamma flux measurements in water or in immersed shielded equipment.

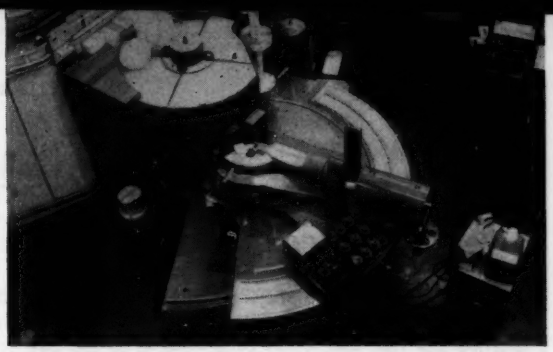
MELUSINE-type reactors are very useful indeed for all work requiring instantaneous fluxes of 5×10^{12} n/cm^2 sec or integrated fluxes of 10^{19} n/cm^2, especially for fast neutrons. Owing to the liquid protection afforded, irradiation loops can be prepared at lowest cost and within the shortest time. Besides, it is possible to handle them while still shielded and to remove them without shutting down the reactor.

For teaching work and measurements on a cold reactor, it is desirable that a spare, low activity core be available in the swimming pool.



With a maximum peak power rating of 2MW, the swimming pool reactor MELUSINE was designed and built by Indatom on behalf of the Commissariat de l'Energie Atomique.

Ancillary Features of Research Reactor Installations



Neutron diffraction apparatus at Munich. An example of the purpose-designed experimental equipment used in reactor experiments.

RARELY will a research reactor be installed in a functionally designed, lavishly equipped building, provided with all the ancillary services that operators and research workers would like. In many instances the reactor will have to be tailored to a building already in existence and because of financial restrictions ancillary services will be kept to the minimum. Such considerations will, however, not be allowed to prejudice the safety of either the reactor or associated laboratories nor unduly limit flexibility of operation.

Provision must be made, for example, for the treatment of effluent whether this be gaseous, solid or liquid. For water-cooled reactors, the reactor proper will contain appropriate demineralization facilities and, at the very least, adequate dump tank capacity to accommodate the full circuit volume in the event of a fuel element failure. For more highly rated reactors such as the swimming pool type much more comprehensive systems will be installed capable of treating large volumes of contaminated liquid. In general, the same systems will be able to cater for the active effluent from the associated laboratories from floor washings, fuel element rinsings and the like, but it is necessary clearly to dissociate ordinary domestic drains from those where wastes are likely to become contaminated. Adequate monitoring equipment must be installed to determine the activity levels in the various liquors.

Only in special installations will gaseous effluent be a problem. From the reactor system itself and from the associated laboratories or containment area, active gases that need to be discharged will be of low activity and after suitable filtration can be discharged to atmosphere. Clearly a centralized system is desirable with full monitoring equipment installed and appropriate provision must be made for changing of the filters at periodic intervals. It is unlikely that open α-sources will be handled by the organizations responsible for the reactor and although the universities may, for example, undertake work on toxic compounds such as plutonium or beryllium, these will, in general, be in special installations purpose-designed for the particular work in hand.

One of the most important facilities associated both with reactor operation and with the building up and taking down of experiments is adequate lifting gear. For the smaller (up to 10 kW) reactors a small jib crane is adequate to deal with the fuel element handling but for the general servicing of equipment an overhead travelling crane with full XY traverse is desirable. In general, a capacity of about 3 tons will be acceptable but for swimming pool installations this should be increased to 10 tons in order to accommodate the more heavily shielded fuel element flasks. In this context it should be noted that the standard flasks for transporting DIDO type fuel elements weigh 13½ tons and, to allow these to be handled, AEI at their Aldermaston laboratories have installed a 15-ton crane over their underwater cropping plant so that these flasks can be loaded directly on to a lorry. Where funds do not allow the provision of adequate craneage fork-lift trucks provide an almost equal alternative, supported by appropriate pallets capable of handling the heaviest single units of shielding likely to be encountered (this might vary from a few cwt. to 13½ tons). There is room, also, for the use of compressed air supported platforms (crude " hovercrafts ") run from the laboratory compressed air supply. For the accurate positioning of low-power shielding walls or the setting up of cumbersome plant, air-cushioning can provide a most elegant solution.

In general the laboratories associated with research reactors outside the U.K. AEA will be handling relatively low activity materials and of small bulk. Few experiments will be centred on active material of more than a curie in strength. As a result 4-in. lead walls to handling cells are all that are likely to be required and operations by tongs rather than master-slave manipulators will be the order of the day. For the same reason, small standard lead containers for the transport of materials within the establishment are all that will be required and fuel handling flasks will be able to accommodate any exceptional irradiation pieces. The counting equipment used will also be, in general, of conventional design except that greater attention will be paid to spectrum analysis.

Flux monitoring is largely carried out by foil techniques but more precise methods of measuring energy deposition and fluxes are likely to be necessary and counting equipment capable of working at very high fluxes and at high temperatures.

It seems unlikely that automatic counting will supplant to any great extent manual operation but clearly there will be an increase in the requirements for data handling and computer equipment to cope with the greatly increased volume of measurements emanating from the laboratories. Initially universities and industrial establishments are likely to use computers already available to the individual establishment but the volume of work may require the installation of special equipment.

Both from an instructional and an operational point of view analogue computing facilities are likely to be always required. The complexity of the installation will vary from institution to institution and will be a function of the maximum reactivity invested in experiments. But for university teaching and for investigating the kinetic behaviour of new set-ups in large reactors a simulator will be essential. Similarly there is also likely to be a demand for mechanical simulators such as was built for the opening of JASON where control rods and priming sources, etc., are reproduced on a model. Complementary to this visual simulation of in-core components the use of close-circuit television is invaluable not only to check in-pile behaviour but also to assist in the administrative control of the laboratory complex.

Only for the larger reactors (greater than 1 MW) are sub-critical facilities, capable of duplicating in essence the reactor core and associated loops, likely to be necessary although the sub-critical assembly will still remain an essential part of university nuclear engineering research, the reactor being used as a neutron source perhaps alternating with a pulsed source of neutrons.

AEA Contracts with Industry

Steady Increase in Development Content

BECAUSE of its weapons commitments, the annual reports of the Atomic Energy Authority do not permit a detailed analysis, and it has been difficult in the past to assess the contribution that industry is continually making to their capital building and research and development programmes. The U.K. AEA have, however, agreed to release outline figures of their expediture involving development, as it directly affects general industry in this country.

The AEA's contract spending can be classified into "manufacturing" and "research and development." In the first group can be included: stores, where this covers standard items held in stock, or alternatively, standard commercial off-the-shelf equipment; equipment that does require certain modifications but is of a type that is sufficiently well established for the development work to be considered as coming within normal terms of business. Research and development contracts are designed to cover items of plant or processes or materials which are in the form of prototypes or are completely novel, and also the development of ideas or principles for the improvement of existing equipment.

Whilst manufacturing contracts can follow normal commercial purchasing practice the uncertainties associated with development work inevitably require a large measure of co-ordination between the technical proposer, the contracts branch and the company concerned. This must be true not only in the initial stages but throughout the progress of the work. As a safeguard the AEA requires as close an estimation as possible of the cost of the development programme and the decision to go ahead with a project will be based partly upon this cost and partly, naturally, upon the technical merit of the offer.

Inquiries are issued by the individual Groups who are invested with authority to deal with projects for which competitive tenders are obtained and where these are within their financial powers. Where competition is not obtained, approval of the London Office is required for all orders exceeding £5,000. On major contracts of this type and on competitive contracts exceeding £100,000, the signature of the AEA's director of contracts in London is required.

Selection of Companies

Where possible, development contracts are put out to tender to selected companies with established expertise in the fields likely to be covered by the contract. Although for certain simple classes of mechanism there may be a great number of companies able to undertake the work, in general the number is limited by the particular skills involved. The Authority maintains a central, confidential register of companies, copies of which are lodged with the Groups; information on companies' activities is augmented by inspectors' comments on the facilities available and a record of past experiences. Companies with research and development effort to spare can notify any of the Groups' contract branches or the director of contracts at the London Office, and their names will be recorded upon this register. (The Authority also publishes a pamphlet—"Information for Contractors" which can be obtained from the director of contracts at 11 Charles II Street, S.W.1). Should projects then arise which fall within the scope of a particular concern some form of further inspection is likely to take place to ascertain the company's competence to undertake the specific job. Although it might be expected that the geographical location of the company would be of material importance, the Authority claims that its inspectors are widely distributed over the country and this is not a major factor.

Although tender prices will not entirely govern the placing of the contract they will have a material influence. The technical group, however, raising the contract always has a major say in the choice of company and may even, because of past experience, recommend that a particular company be chosen. Such a proposal will always receive close scrutiny by the contracts branch to whom it must be justified.

Because of the great variations in the difficulty of carrying out projects, the value of the experience gained, the commercial potential of the end product, there will clearly be a tendency to see that companies who handle difficult jobs skilfully are considered for the more straightforward contracts which tend to be more profitable. This is not an automatic policy but as in all customer/supplier relations the past will have a significant influence on the future.

It is important to remember in this context, that in a new field such as nuclear engineering the customer is likely to require standards of workmanship, nuclear cleanliness, extensive testing or other specialized services not normally encountered in more conventional engineering practice. The company engaged on work of a development character must also be prepared for numerous design alterations, and be able to understand and work in accordance with the peculiar conditions demanded by physics and metallurgical compatibility, remote maintenance, etc. As a result the experienced concern and the concern willing to invest its own finance in obtaining "know-how" is likely to be preferred to the newcomer who is likely to require extensive teaching in the principles of nuclear technology. The AEA has been required to spend a great deal of time in building up specialist expertise in industry, not merely in the big groups but in the smaller companies prepared to specialize in the development and production of such items as remote handling gear.

One of the problems that the Authority has encountered is the tendency of companies to enter the nuclear development field with high initial enthusiasm, which then proceeds to tail off as a greater appreciation is gained of the difficulties of the work and the limited quantity production potential. On the other side some companies will maintain that they have been led into expensive development work in the belief that production contracts would follow and these have not materialized.

In order to offset this fall off in interest with time the running contract system has been introduced. Running contracts are placed with companies willing to put at the disposal of the Authority certain design and development facilities and a certain number of trained staff at an agreed price. Although this does not short-circuit the procedure associated with raising the contract nor eliminate competitive tendering, it does save time in negotiating the detailed clauses and, more important, the company can be reasonably assured of a steady flow of work from the Authority and the Authority on its part can be assured of a

continuing capacity. Running supply contracts are greatly used to cover the needs for stores materials and spares of a standardized type.

In the past the Authority's largest expenditure on specialist services has been via the former Industrial Group who have purchased approximately £100 million-worth of equipment during the past 10 years excluding stores and operating materials. Major plants covered by this sum are the production reactors at Calder Hall, and Chapelcross, the processing plant at Windscale, the diffusion plant at Capenhurst and the fuel element production plant at Springfields.

At present the AEA's expenditure on plant installations is running at about £15 million per annum. Over the past 12 months rather less than £3 million of this involved development effort due to its novelty, but a marked change is coming over the Authority's needs for manufacturing work in the next two or three years and the development work will increase appreciably. This reflects the completion of the major production factories mentioned above and the Authority's desire to encourage a greater technical contribution from industry in its new experimental plant.

The range of requirements is very wide, extending from whole sections of the AGR experiment or the new Windscale separation plant and fuel element examination caves down to small pieces of specialist mechanism; a range of cost extending from £3-4 million down to £1,000. Similarly, the probable future production associated with such development is very variable. Many items will have no future markets and will be essentially "one offs." Others, such as work on the AGR, although not leading directly to repetition contracts may serve as valuable prototype experience for subsequent production runs.

Where a specialist class of equipment has a potential market the AEA has deliberately encouraged companies to undertake complete design and development. An example of this is in the manufacture of in-pile irradiation facilities for research reactors. Although loops are individually designed, they retain strong family characteristics requiring extensive experience in the appreciation of safety problems, compatibility etc., of nearly the same order as in reactor design. A company acquiring this experience is given scope for standardization and is able then to provide a full design and manufacturing service not only to the AEA but to the operators of research reactors abroad.

For the bigger projects clearly a great deal of chemical engineering and heavy plate work will be involved; for loop work a comprehensive mixture of fine machining, heavy engineering and instrumentation is required. There is also a widening field for the development of small mechanisms with particular reference to the remote handling of radioactive materials. The value of this last category can be placed as around the £¼ million/an. mark.

The Development and Engineering Group will have another demand upon industry, for development contracts not associated with manufacturing, to the value of about £¼ million/an., a figure which may rise. Some of these will be with the universities but the majority will be with industry and particular emphasis will be placed on the techniques associated with the canning of fuel elements.

At Harwell, similar expenditure is running constant at around £1.3 million/an. of which approximately £1 million will be spent in industry. Like the D. and E. Group the value of individual contracts varies over a wide range and figures of £1,000 to £¼ million can be quoted. In Table 1 we give the breakdown of a recent group of contracts in which numbers are given against value with some indication of the fields in which they apply.

Table I—Analysis of Harwell Contracts

Range of values	Av. Value	Number	Electronics	Metallurgy	Reactors
< £15,000	£3,000	65	28	20	5
£15,000—£25,000	£20,000	15	6	—	—
£25,000—£100,000	£37,000	18	2	7	—
> £100,000	£370,000	4	—	—	1

Integrating these figures then, the Authority was spending last year with industry at the rate of roughly £10-12 million/an. in manufacturing contracts and around £5 million in contracts involving development. Over the next three years the last figure is likely to increase by another £5 million whilst the first will decrease by a somewhat smaller amount.

It must be emphasized that none of the sums quoted above includes standard stores, works and bricks nor the supply of raw materials. Each of these categories will constitute a very big item; for example, the purchasing of uranium and fuel element cans represents a considerable outlay by the Authority each year. More detailed discussion is not possible. It would seem reasonable to suppose, however, knowing the Authority's staff and its commitments in production and research, that over the next year or so the Authority (excluding the Weapons Group) will be purchasing standardized and specialist equipment, and design and development skill to a value of £20 million/an. and raw materials, items for further processing and works and bricks to the value of another £30 million/an.

Nuclear Engineering in Germany

By H. L. J. BURGESS

THE present situation in the field of nuclear energy in Western Germany carries the imprint of a number of conditions resulting from circumstances symptomatic of post-war Germay, in particular.

1. The long absence of legal foundations.

2. The effect of federalism—the prevailing political concept.

3. The lack of a national tradition in the evolution of nuclear energy.

The Legal Position

Germany's constitution, in its original form, ignored the whole complex of atomic energy. A two-thirds majority in the Bundestag was required to make the necessary amendments and an initial attempt by the Government two years ago was unsuccessful for political reasons. The Act was finally passed on December 3, 1959, and sent to the Bundesrat.

The essential purpose of the Nuclear Energy Act is to protect—thereby releasing potential initiative held back till now by uncertainty over financial and physical risks. Declaredly, the Act is designed to allow the Government to promote and guide initiative in science, industry and trade but, in no circumstance, to operate directly in the field.

Until the Act becomes fully operative the only legal basis

is Law No. 22, promulgated by the Allied High Commission (Occupation Authorities) at the time with the aim of prohibiting, wholesale, all activities in that field. Gradually, the scope of this law was reduced and by the provision of a permit system the initiation of certain activities, such as research, was facilitated on individual application. When Germany regained her sovereignty in 1955, the administration of the law was transferred to the Bundes Ministry of Nuclear Energy: it could not be revoked because of the protection it afforded.

As a result, each Land, operating or building a research reactor, passed a provisional nuclear energy law in which many of the clauses constituted a faithful copy of the draft of the Bundes Act. Safety measures and liabilities arising from operational risks were assessed in accordance with the financial strength of the respective Land. In Geesthacht (Hamburg), for instance, the 5-MW reactor could only be run at 200 kW maximum.

In detail, the Bundes Nuclear Energy Act consists of three parts: It stipulates and normalizes licensing procedures; it establishes the powers under which the Government can issue safety regulations and organize adequate supervision by the State; it determines maximum liability by the State with respect to risks of a magnitude larger than can be covered by the established insurance market.

The first action the Bund is to take, once the new Act is in force, is the issue of "Safety (Radiation)—Regulations." Close supervision by the State of the handling of radioactive materials at all stages will be instituted and licences granted only after inspection of the equipment at the disposal of the applicant. Permissible radiation levels will be substantially those recommended by the I.C.R.P. and Euratom.

Liability by the State extends to compensation for physical damage and deterioration of health but excludes claims for pain and suffering. Generally, the Act distinguishes between two classes of beneficiaries: (a) the operator of reactors, fuel element processing plant and associated activities, and (b) the operator and/or trader in possession of, and/or using, radioactive material. In the case of (b) no maximum figure is stipulated for the liability by the State as accidents on a disaster scale are improbable. At the same time, acceptance of liability by the State in each individual event is more severely conditional than in connection with the activities summarized under (a). Here the approach is similar to that of the Anderson-Price Act in the U.S.A. The operator is legally bound to obtain conventional insurance cover at a value to be laid down by the authorities in the licence and the Bund Treasury will indemnify him against any additional compensation commitments up to a total of about £42 million arising from any one event. The maximum compensation payable to an individual on account of reduced earning capacity due to health damage is an annual pension of £1,200 for life.

No provision is made in the Act for the establishment of State-owned or State-sponsored research centres or development installations. It is the official view that such institutions are incompatible with the idea of free trade, private industry and independent scientific development, and can only be made to work in a largely nationalized commercial community. There is considerable opposition to this interpretation in certain quarters of industry.

The Effects of Federalism

Post-war Germany's political creed is Federalism. The Laender enjoy a large measure of autonomy, particularly so in cultural matters, which include the organization of teaching institutions at university level, and research. Interference by the central authorities in the respective policies of a Land is anathema. In these conditions, local ambitions are exercised freely and a good deal of rival planning occurs, in the sense that each Land aims at owning for itself a complete set of scientific apparatus which will facilitate research on the broadest possible basis, independently of parallel activities in other parts of the nation.

Six Laender have acquired seven research reactors between them: Hessen-Frankfurt (1), Berlin (1), Bavaria-Munich (1), Lower Saxony-Hamburg (1), Baden Wuerttemberg-Karlsruhe (1) and Nordrhein Westphalia-Juelich (2). The first four are operational, the remaining three building. The first two are nearly identical and of 50 kW each, the third, 1 MW; the fourth, 5 MW; Karlsruhe, 12 MW, and Juelich, 5 MW and 10 MW. All are of foreign design except Karlsruhe, representing a German version of the Canadian NRX.

Frankfurt, Berlin and Munich are attached to universities, Hamburg is run by the Shipping Studiengesellschaft, and Karlsruhe and Juelich are to be developed into major reactor research centres of roughly the same size, both fully equipped with laboratories for all associated investigation work and installations for the production of isotopes on a commercial scale. Each of these centres is estimated to cost about £9 million when completed.

There is no apparent co-ordination of effort, no centrally planned selection and allocation of special tasks. Each reactor station seems to attempt studies over the whole range of possible subjects. All are said to suffer from the severe shortage of first-rate nuclear specialists in Germany at large, and none, it is claimed, disposes of funds commensurate with their professed programmes.

In a legal sense, the introduction of the Nuclear Energy Act will do little to change this state of affairs. Basically, the Ministry is not endowed with greater power. At one stage in the preparatory work for Karlsruhe it became clear that the funds subscribed jointly by industry and Land were grossly inadequate. The Bund offered to make up the difference but the sum in question would have given the Bund a dominating position on the management board. The offer was rejected and a special holding company formed, charged with the task of securing the necessary finance. Whatever the reasons for the rejection and whatever hopes the Ministry may have associated with that offer at the time, the idea of planning State-sponsored research programmes has never been attempted in earnest and has since been abandoned by the Ministry.

In practice, however, the Ministry is not as powerless as could be adduced. The Bund is approached most regularly—and agrees—to assist in financing the various projects. The Ministry considers it a primary objective of its policies to help in the establishment of nuclear research and training centres as quickly as possible. It virtually wields the powers of a financier.

Inevitably, the Ministry is accused of not using these powers in the right manner; in fact, of ignoring them. By refusing cash, it could at least stop major duplication of effort but it would never try, so the critics say.

On the other hand, according to the official version, the Ministry is a purely administrative body with a correspondingly small staff—150. All expert knowledge and advice, if and when required, is made available through one of its two supporting bodies, the German Atomic Commission and the Reactor Safety Commission. The former has 200 members recruited from specialists at all levels of science and industry, and the latter has about 15 members, including experts from complementary disciplines.

In addition to its normal functions, the Ministry is associated with the work of a number of special committees in the general organization of the Government,

such as the Atomic Energy Laender Committee, the (Inter-Ministries) Co-ordination Committee and the Parliamentary Committee on Atomic Energy. The Ministry's budget for 1958 amounted to £12 million as compared with £4 million in 1956. Significant items of expenditure are: £5 million—contributions to the re-equipment of research establishments generally; £1 million—contributions to the construction of research reactors in various parts of the country, and £2 million—contributions to expenditure on the Karlsruhe reactor alone. About £3.5 million are contributed to Euratom direct from the Bundes Treasury.

Lack of a Tradition in Nuclear Science

The Germans entered the field in 1955, some 15 months before Calder Hall was inaugurated, i.e. at a time when the business-end of nuclear energy evolution began to take shape. Still today, in the countries with a tradition in this respect, the general attitude can be defined as one of looking upon the research and purely experimental side as the factor overshadowing and controlling the pace at the industrial business end. Right from the start, German industry proper seems to have placed the emphasis in the reverse order. Business and truly competitive action in the world markets are the immediate goal, and one cannot resist the impression that, generally, the scope and volume of development work ahead is somewhat underrated, and the need for sharing development results is largely ignored.

There are five concerns supplying reactors and associated equipment, divided into two camps. Interatom, Babcock and Wilcox and, notably, AEG, are in one camp, and Arbeitsgemeinschaft BBC-Krupp (ABK) and Siemens in the other. The above criticism does not apply to the "Three" as they do little development of their own in Germany. Interatom, Babcock and Wilcox and AEG are importers (at least of design), all practising similar policies, i.e. maintaining a small staff to attend to problems arising locally, drawing on their extended experimental facilities abroad for major investigations and tending to offer designs thoroughly tested and explored in previous applications. So far between them, the "Three" have received virtually all orders placed by German clients but this is unlikely to continue indefinitely. Their outlook is international and they advocate step-by-step progress, building up on the past. Thus, they are in opposition, not only in competition, to the other camp.

The popularity (within Germany) of the other camp (as is to be expected) is *a priori* higher. They are resolved, almost publicly pledged, to produce *German* reactors and their influence in Government circles is considerable. The Industrial Plan (see below) adopted by the Government is officially stated to be tailored so as to suit its main purpose —i.e. that of facilitating the speedy development of a *German* power reactor.

Siemens has a staff of 200 to tackle all problems relevant to power reactor development and design. ABK has a staff of 40, soon to be increased to 80. Siemens is known to be vastly more interested in its own development work than in the facilities offered through its association with Westinghouse.

The most advanced German power reactor project is the Schulten Pebble-bed reactor under development at the ABK. A prototype of 15 MW(e) operating at 700°C will be built at Juelich and is now on the drawing board. The project is a major topic of conversation among all German specialists and, no doubt, the German attitude towards foreign reactor designs, as well as their own industrial policy, will be considerably influenced by the performance results of the experimental type.

The Industrial Plan has been initiated by the manufacturing industry. The electricity undertakings themselves are still rather reserved in their attitude to nuclear power stations but five special organizations have been formed by them to facilitate execution of the industrial plan. These are:—

AKS (Stuttgart), AVR (Duesseldorf, Juelich), GEA (Bavaria-Munich), RWE (Essen, Kahl) and SKW (Hanover).

The Industrial Plan visualizes the installation of 500 MW of nuclear power by 1965, in five units of 100 MW, each reactor being of a different and, where possible, of German design, as follows:—

AGR, D_2O-cooled, BWR, HT (Schulten) reactor, OMR.

15-MW(e) units of each type will be installed as experimental forerunners (see Kahl and Juelich), except in the case of the OMR, which is now in a state of flux (see p. 93).

It is estimated that the Industrial Plan will require the supply of the following quantities of material:

Natural uranium, 400 t; 1.5% enriched U, 40 t; 20% enriched U, 300 kg; graphite, 2,000 t; heavy water, 150 t; zirconium, 60 t; thorium, 50 t.

The use of nuclear power for electricity generation is not considered an urgent necessity but Germany is already now an importer of primary energy and it is proposed, therefore, to urge developments so that nuclear power stations of reasonable size can be added to the network after 1965. In 1957, the capacity was 21,500 MW and the consumption 95 MkWh. In 1965, the consumption is expected to have risen to 170 MkWh and the installed conventional plant capacity to 38,000 MW.

The financing of the power reactor programme will be organized as follows:

The expenditure involved in connection with feasibility and design studies will be financed up to 50% by Government loans not repayable if the study is abandoned.

Actual building cost will not be financed by the State as it is expected that the operator will be able to make his own arrangements, if necessary, through established channels in the capital market. On the part of the Government, it is argued that the capital investment for a coal-fired station ranges from £40 to £50/kW, rising to £200/kW for hydro-electric stations. A nuclear power station of the 100-MW type is estimated to require £100 to £180/kW, i.e. a total capital of £10 million to £18 million. This figure is only one-tenth of the total sum invested annually by the power industry. But there is a vague promise by the Government to grant what is termed "start-hilfe."

The Government is willing, however, to compensate the operator, partially (at a rate still to be determined), for operational losses provided that he agrees that the respective arrangements cover the whole period of the service life of the station and allowance is made for repayment of some or all of the moneys made available by the Government should operation prove profitable in a subsequent period.

Relations with Euratom

To complete the picture, a few words should be added on relations with Euratom. Comments by German industrialists are sparse and it is difficult to sum up the general attitude accurately. As has been made plain in the above notes, Germany's atomic industry is engaged in a powerful drive to manage its own affairs. While this drive is on, all concerned obviously prefer to concentrate on efforts not involving extra-mural interests and, to the detached observer, it appears that their approach to Euratom projects is prompted by a sense of obligation rather than genuine enthusiasm.

CIRCULAR GRILLAGES

Their Design and Analysis

By R. K. LIVESLEY
(*Department of Engineering, Cambridge University*)

This article describes some features of the behaviour of square-mesh grillages with circular boundaries, such as are used in reactors for supporting the graphite stack. An interesting aspect is the tendency for the load on the supporting skirt to be concentrated at points at 45° to the mesh; designs to overcome this are examined.

THE type of graphite-moderated gas-cooled reactor at present under construction for power stations in this country and elsewhere requires the support of several thousand tons of graphite within the reactor pressure vessel, and as the graphite has little inherent strength it must be supported by a rigid platform. In addition to being structurally safe, this platform (diagrid) must be sufficiently stiff to prevent serious deformation of the core under load, and should also be designed to transmit the weight of the graphite through to the foundations in as uniform a manner as possible.

One approach to the problem, which will be discussed in the present article, is to construct the platform out of a grid of steel beams, with a covering of steel plates to carry the graphite bricks, and to support it by a circular skirt. The beams in such a design can conveniently be deep plate-girders of constant or varying section, the top plates which support the graphite also acting as the top flanges of the beams. Even though the boundary of the platform is (at least approximately) circular, it is simplest from a constructional point of view to use a grid with a square mesh. It is this mixture of rectangular and polar co-ordinate systems which makes the general analysis of such structures difficult.

Uniform Depth Grillage, Boundary Support

The first analysis we shall describe is that of a design in which all the beams are of constant depth, the circular supporting skirt forming the boundary of the grillage. The surface loading due to the weight of the core extends over a circular area somewhat less in diameter than the grillage, being uniformly distributed within that area. For the purpose of analysis this distributed loading is replaced by equivalent concentrated loads at the mesh points, and the grillage is assumed to be simply supported at its boundary. One octant of the grillage is shown diagrammatically in Fig. 1; due to symmetry, only the behaviour of this octant need be considered.

The maximum stress and deflection clearly occur at the centre of the grillage. A rough approximation to the values of these quantities may be obtained either by applying isotropic flat plate theory or by imagining that at each mesh-point the load is divided equally between the two beams which intersect there. If we neglect torsional moments in the beams and use the latter approach we can immediately write down the loading on one of the central beams (A) and evaluate the maximum moment and deflection. For this particular design the approximate maximum bending moment derived by this method exceeds the value given by more exact analysis by 19%, while the corresponding figure for the deflection is 22%.

A more exact analysis requires a consideration of the redundancy of the system. One might treat the deflections

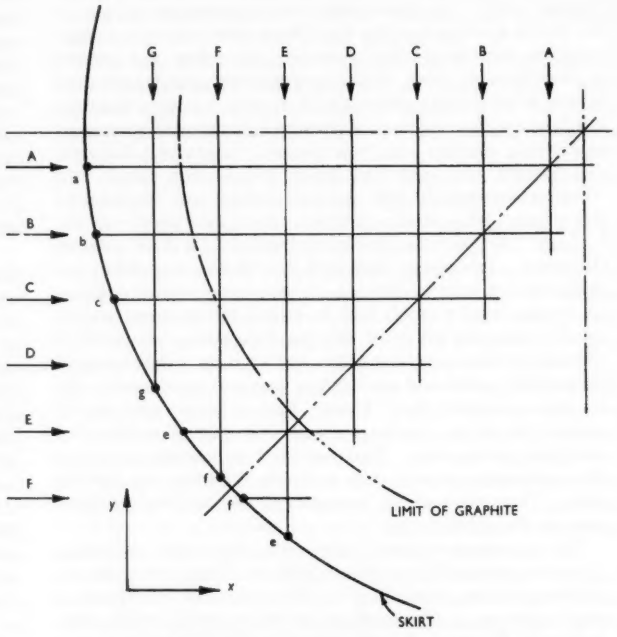


Fig. 1.—Arrangement of a grillage simply supported on a circular boundary.

of the mesh-points as the unknowns, but in fact the number of variables is somewhat reduced if the basic unknowns are taken to be the loads carried by the x-direction beams at the mesh-points. If this is done it is not necessary to introduce unknowns at mesh-points lying on the diagonals, since these are axes of symmetry on which the loads must divide equally. If torsion is considered it becomes necessary to introduce redundant moments as well as forces at each mesh-point. As the beams in the design considered are in fact very deep plate girders, it seems legitimate to neglect their torsional stiffness, especially as such neglect leads in general to a slight over-estimate of the maximum stress and deflection, and is therefore on the safe side. The effect of shear distortion in the beams, on the other hand, is to increase the deflections and should therefore be

included. In this particular design the increase in central deflection due to shear is of the order of 6%.

It will be seen that for the design shown in Fig. 1 there are 19 unknown redundant forces. These may be obtained by evaluating influence coefficients for the mesh-points of the seven different types of beam in the system, and writing down an equation for the compatibility of vertical displacement at each mesh-point. Such a process is numerically

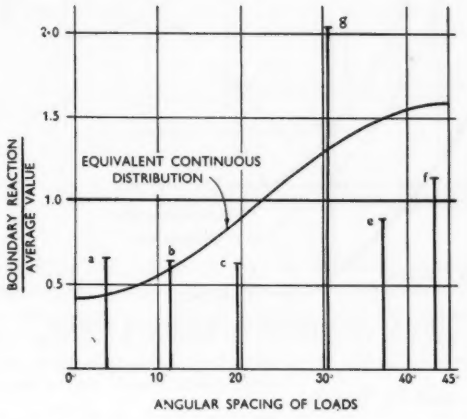


Fig. 2.—Variation of support reactions for the grillage shown in Fig. 1.

somewhat tedious but quite straightforward, and has been described for a similar design by Edwards, Gill and Perkins[1]. The equations can easily be solved on a digital computer, and if a succession of similar problems had to be analysed it would be economical to programme the whole computation. Alternatively, the general grillage programme developed by Lightfoot and Sawko[2], which takes account of torsional stiffness but not shear, could be used to carry out a completely automatic analysis.

Although the analysis is straightforward, the results show several interesting features which could not have been easily foreseen. The deflected form of the grillage does not depart significantly from one of radial symmetry, but the distribution of boundary reaction shows considerable variation. What happens is that the beams E, F, and G, being considerably shorter and therefore stiffer than A, B, and C, tend to support the latter beams instead of sharing the loading equally with them. This means that the beams E, F, and G transmit considerably more than their share of the total load (68%, in fact) to the supporting skirt. The distribution of vertical load on the skirt is shown in Fig. 2, together with an "equivalent" continuous distribution obtained by taking the first two terms of a Fourier series. A similar analysis for the case of a concentrated load at the centre of the grillage shows this effect to an even greater extent. In the latter case the three points a, b, and c carry virtually no load, and in fact the reaction at the end of beam A has a small negative value.

Although it is fairly straightforward to analyse any particular design of grillage, it would be useful to have a more general solution. It would be interesting to discover, for example, how the ratio of grid spacing to grillage diameter affects the load distribution on the supporting skirt. (The non-uniformity described above persists in several other cases analysed by the author.) A particularly useful solution would be the case of a uniform grillage with an infinitely small mesh size. This is equivalent to replacing the grillage by an anisotropic plate, whose differential equation may be written:

$$\frac{\delta^4\omega}{\delta x^4} + 2\lambda \frac{\delta^4\omega}{\delta x^2 \delta y^2} + \frac{\delta^4\omega}{\delta y^4} = \frac{q}{D} \quad . \quad . \quad . \quad (1)$$

where $q(x, y)$ is the applied loading and λ is a measure of the torsional stiffness. This equation may be written in the form:

$$\nabla^4\omega - 2(1-\lambda)\frac{\delta^4\omega}{\delta x^2 \delta y^2} = \frac{q}{D} \quad . \quad . \quad . \quad (2)$$

Transformation of equation (2) into polar co-ordinates is not too difficult, and it should be possible to obtain a series solution in terms of harmonics. It must be remembered, however, that the boundary reaction involves third differential coefficients of the deflection ω and it might be difficult to obtain these with sufficient accuracy for the solution to be of value.

Design for Uniform Boundary Support

The non-uniformity of the support reactions described above is not a sufficient reason for discarding the uniform grillage as a possible type of design. It does suggest, however, the desirability of finding designs which do not suffer from this defect. One could, of course, achieve uniformity by placing packing pieces of appropriate thickness under the ends of the beams, but this would require a complicated erection procedure to be satisfactory. An alternative approach is to vary the flexibility of the beams.

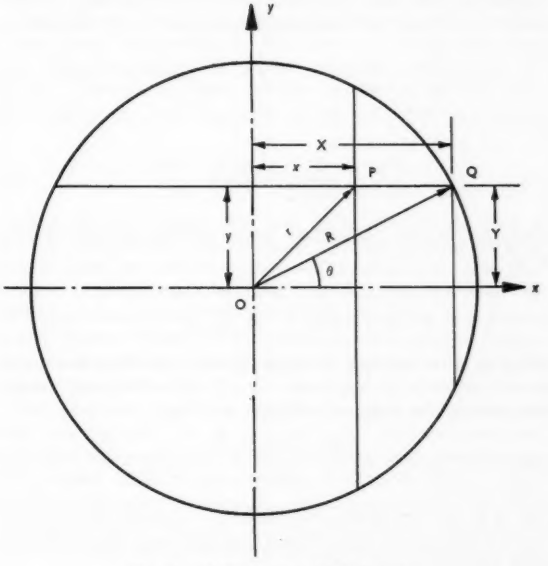


Fig. 3.—Grillage of variable inertia.

We now consider the design of a circular grillage of radius R and grid-spacing a, where a is small compared with R, simply supported with zero deflection at its boundary. We assume a uniform loading equivalent to a load W at each mesh point. We show first that if W can be distributed equally between the beams at each mesh-point then the support reaction round the boundary will be uniform.

Consider the beams which meet the boundary at the point Q in Fig. 3. If the load transmitted to any beam at any mesh-point is always $W/2$, we may treat each beam as though it were carrying a uniformly distributed load of

intensity $W/2a$ per unit length. Thus the beam in the x-direction will apply a load:

$$WX/2a=(WR\ cos\ \theta)/2a$$

to the support at Q, while in the same way the beam in the y-direction will apply a load:

$$WY/2a=(WR\ sin\ \theta)/2a.$$

Now on the boundary in the neighbourhood of Q there are $(cos\ \theta)/a$ supports per unit length of boundary for the x-direction beams, and $(sin\ \theta)/a$ supports per unit length for the y-direction beams. The total load per unit length of boundary at Q is therefore:

$$\frac{Wr\ cos\ \theta}{2a}\cdot\frac{cos\ \theta}{a}+\frac{WR\ sin\ \theta}{2a}\cdot\frac{sin\ \theta}{a}=\frac{WR}{2a^2},$$

and is independent of θ.

The next problem is to find a distribution $I_x(x,y)$ for the moment of inertia of the x-direction beams, and a similar distribution $I_y(x,y)$ for the y-direction beams, which will give compatibility of deflections at all the mesh-points under the load distribution postulated. The basic differential equation for the x-wise beam passing through the point P is:

$$\frac{\delta^2}{\delta x^2}\left(E\ I_x\frac{\delta^2\omega}{\delta x^2}\right)=\frac{W}{2a}\quad .\ .\ .\ .\ .\ (3)$$

Integrating this twice and putting in the conditions of zero shear at $x=0$ and zero bending moment at $x=X$ we obtain:

$$E\ I_x\frac{\delta^2\omega}{\delta x^2}=\frac{W}{4a}(x^2-X^2)=\frac{W}{4a}(x^2+y^2-R^2)\quad (4)$$

or

$$\frac{\delta^2\omega}{\delta x^2}=\frac{W}{4aE}\cdot\frac{x^2+y^2-R^2}{I_x\ (x,\ y)}\quad .\ .\ .\ (5)$$

Similarly for the y-direction beam passing through P we have:

$$\frac{\delta^2\omega}{\delta y^2}=\frac{W}{4aE}\cdot\frac{x^2+y^2-R^2}{I_y\ (x,\ y)}\quad .\ .\ .\ .\ (6)$$

Our aim is to produce a design, rather than find the most general solution of equations (5) and (6). We shall therefore choose the simplest solution, putting:

$$I_x(x,y)=I_y(x,y)=I_o\left\{\frac{R^2-(x^2+y^2)}{R^2}\right\}=I_o(R^2-r^2)\Big/R^2\quad (7)$$

That is to say we make the moments of inertia of any two beams equal at the point where they intersect, the variation being dependent on r only.

Equations (5) and (6) become:

$$\frac{\delta^2\omega}{\delta x^2}=\frac{\delta^2\omega}{\delta y^2}=-\frac{WR^2}{4a\ EI_o}\quad .\ .\ .\ .\ (8)$$

or alternatively:

$$\nabla^2\omega=-\frac{WR^2}{2a\ EI_o}\quad .\ .\ .\ .\ .\ (9)$$

whence:

$$\omega=\frac{WR^2}{8a\ EI_o}(R^2-r^2)\quad .\ .\ .\ .\ (10)$$

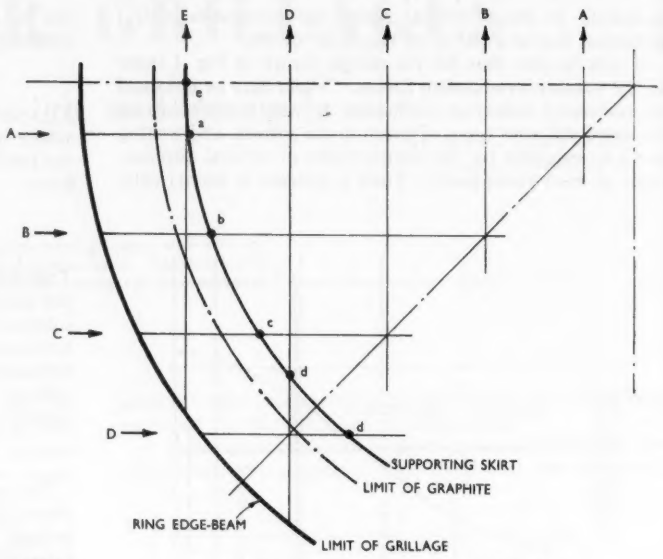


Fig. 4.—Arrangement of Cantilevered Grillage.

which may be written:

$$\omega=\frac{\overline{W}}{8\pi EI_o'}(R^2-r^2)\quad .\ .\ .\ .\ (11)$$

where $\overline{W}$ is the total load on the grillage and I_o' is the moment of inertia per unit width of grillage at the centre. The corresponding central deflection is $\overline{W}R^2/8\pi EI_o'$. As $\delta^2\omega/\delta x\delta y$ is zero everywhere, the solution is a "twistless" one, with no torsion occurring in the beams.

If Z is the distance from the neutral axis to the extreme fibre of a beam and p is the value of the stress there, then:

$$\frac{p}{Z}=\frac{WR^2}{4aI_o}=\frac{\overline{W}}{4\pi I_o'}\quad .\ .\ .\ .\ (12)$$

and is constant everywhere, as from (8), the curvature is constant. If the beams consist of two thin plates of constant area A per unit width of grillage separated by a thin web of variable depth $2Z$, so that the moment of inertia of each beam is approximately $2aAZ^2$, we have from (7):

$$I=2aAZ^2=I_o(1-r^2/R^2)=2aAZ_o^2(1-r^2/R^2)$$

whence:

$$Z^2/Z_o^2+r^2/R^2=1$$

so that the beams are elliptical in shape. The bending stress is a maximum at the centre and is given by:

$$p_o=\frac{WR^2Z_o}{4aI_o}=\frac{\overline{W}}{8\pi AZ_o}\quad .\ .\ .\ .\ (13)$$

while the central deflection is:

$$\omega_o=\frac{\overline{W}R^2}{16\pi EAZ_o^2}=\frac{p_oR^2}{2EZ_o}\quad .\ .\ .\ (14)$$

Thus the depth of the grillage at the centre depends only on the permissible deflection and stress, and is given by $Z_o=p_oR^2/2E\omega_o$, while the appropriate value of A can be found from (13).

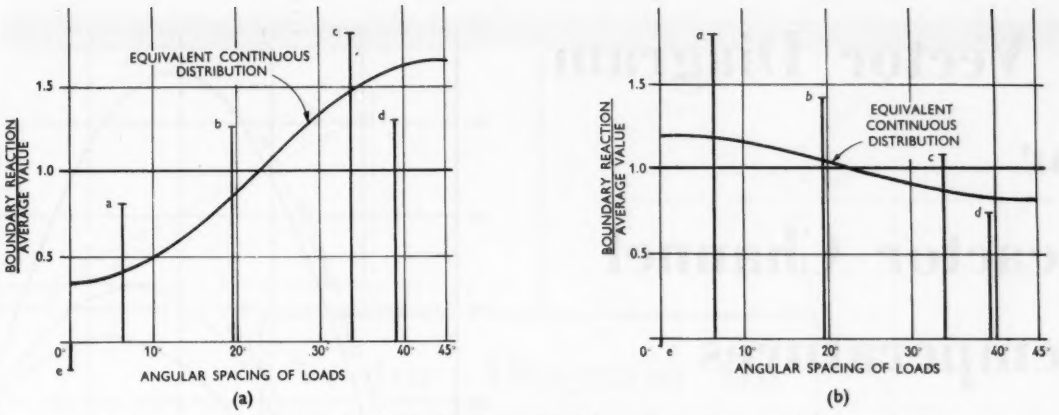


Fig. 5.—Variation of support reaction for the Cantilevered Grillage shown in Fig. 4 with (a) no curved edge-beam; (b) an edge-beam with infinite bending stiffness.

For fabrication reasons it may be necessary to modify this theoretical design. One possible simplification is to make each beam of constant moment of inertia along its length, varying the moment of inertia from one beam to another to give approximately the same stiffness variation as occurs in the theoretical design.

Behaviour of a Cantilevered Grillage

Although considerations of overall reactor design may make it desirable to place the supporting skirt entirely outside the area of the grillage, it is obviously advantageous structurally to make the skirt of somewhat smaller radius, so that part of the grillage is supported in cantilever fashion. This will tend to reduce both the maximum stress and the maximum deflection. An example of such a design is shown in Fig. 4.

This grillage was analysed by a method similar to the one used for the simply supported case discussed earlier. The analysis was slightly complicated by the presence of the ring edge-beam, and as the final design details for this were not complete at the time, it was decided to do two analyses—one with no edge beam present and one with an edge-beam infinitely stiff in bending. Clearly these two analyses provide bounds for the true solution. As before, shear effects are considered, but torsional stiffnesses are ignored. In this design there are nine off-diagonal mesh-points, giving nine redundancies when the ring edge-beam is absent. When the edge-beam is present, a further five redundancies (the forces exerted by this beam or the others) must be introduced, making 14 in all.

Effect of Edge-beam

As might be expected, the ring edge-beam has very little effect on the deflection and stress at the centre of the grillage. The presence of the edge-beam reduces the calculated central deflection by only 4½% and the central bending moment by only 3½%. It is when we turn to consider the edge effects that the true significance of the ring-beam becomes apparent. Without any edge-beam the loads transmitted to the supporting skirt are as shown in Fig. 5a. It will be seen that the concentration of load round the diagonal points is even more severe than it was in the case of the simple grillage discussed previously. This would seem to be due in part to the presence of the beam E in Fig. 4. This beam has negligible effect on beam A, but provides C (and to a lesser extent B) with extra stiffening. The analysis shows that E exerts large downward forces on B and C, and these forces are then transmitted to the skirt at the points b and c.

The introduction of the ring-beam produces the much more satisfactory loading pattern shown in Fig. 5b. Without the ring-beam the upward deflections of the ends of the beams A and B are approximately 40% greater than the corresponding values for D, and E. The ring-beam makes all these deflections equal by applying downward forces to the ends of beams A and B, and upward forces to the ends of D and E, with a consequent redistribution of the loads transmitted to the skirt. It is arguable that the effect of an edge-beam of finite stiffness would be even better. Presumably by a correct choice of stiffness one could reduce the first harmonic in the skirt loading to zero.

Conclusions

Although the author has not been able to develop a general analysis for the uniform circular grillage with a square mesh of arbitrary size, the analysis of particular designs presents little difficulty. The concentration of loading at the diagonal points of the supporting skirt seems to be a general feature of the problem, although the magnitude of the effect certainly depends on the ratio of grid spacing to skirt radius.

The practical consequences of the non-uniformity of skirt loading may not be very serious. It does, however, make the stress analysis of the pressure-vessel much more complicated, and for that reason, if for no other, it may be desirable to develop designs which give a better distribution of support reaction. There may be other ways of achieving this result besides those described in this paper.

Acknowledgment

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REFERENCES

1. Edwards, J. C. M., Gill, S. S., and Perkins, J. "A Method of Calculating the Deflection of the Graphite Support Grid for a Gas-cooled Reactor." *Civil Engineering and Pub. Wks. Review*, Dec., 1958, Vol. 53, p. 1,400.

2. Lightfoot, E., and Sawko, F. "Structural Frame Analysis by Electronic Computer." *Engineering*, Jan., 1959, Vol. 187, p. 18.

A Vector Diagram for Reactor Channel Temperatures

By P. R. J. FRENCH, B.Sc.(Eng.)
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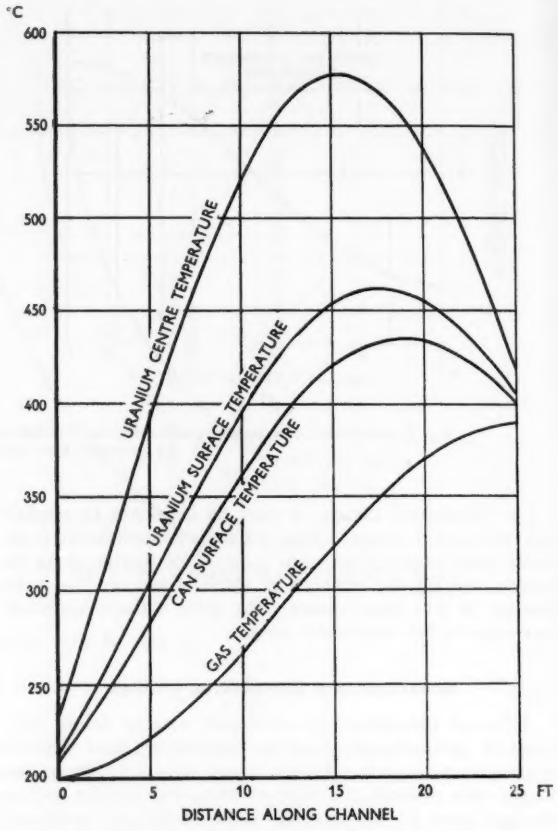
The axial distribution of heat generation in a cylindrical core with vertical coolant channels is approximately sinusoidal. Temperatures can be plotted by means of a simple vector diagram, the construction of which is shown on the following page.



Typical channel temperature distributions in a gas-cooled reactor.

IN a cylindrical reactor core with the coolant channels parallel to the axis of the cylinder, the distribution of heat generation along any channel is approximately sinusoidal. This distribution can be represented by a vector diagram of the type commonly used by electrical engineers to represent quantities which vary sinusoidally with time, provided that rotation of a vector is taken to denote distance travelled along the channel, instead of the lapse of time.

For example, in Fig. 1, the length of the vector OB can be made to represent the maximum value of the local fuel rating, measured in MW/t, while the angle θ between the vector and an initial line OA can represent distance along the channel. The projection OA on the initial line is then a quantity which varies sinusoidally with distance, and can therefore represent the local fuel rating at any point. The value of OA is obviously a maximum when the angle θ is zero, while OA is zero for $\theta=\pm\pi/2$. For the simple case of an axially uniform bare reactor, the local fuel rating is a maximum at the mid-point of a channel, and zero at the ends. Consequently the vector diagram of Fig. 1 can be applied to such a reactor by putting $\theta=\pi x/l$, where l represents the length of the core, and the distance x is measured from the mid-point of the channel, the positive direction of x being that of the coolant flow. The local fuel rating is then proportional to $\cos\theta$.

The total heat taken up by the coolant in passing along the channel to any point x is proportional to the integral of the local heat production with respect to distance along the channel. If the fuel rating varies as $\cos\theta$, the heat content of the coolant, and consequently its temperature, must vary as $\sin\theta$, and can be represented by a vector OC lagging 90° on the fuel rating vector (Fig. 2). It is convenient to take as a reference the coolant temperature at the mid-point of the channel; the projection OD of the vector OC in Fig. 2 then represents the coolant temperature relative to this reference value; it is positive for $x>0$ (i.e., for points beyond the mid-point of the channel), and negative for $x<0$.

It is now possible to construct a diagram such as Fig. 3, in which the point O represents the coolant temperature (T_{co}) at the channel mid-point, the point D represents the coolant temperature at a point $x=\theta l/\pi$, and point E represents the can surface temperature at x. OC is the vector representing the coolant temperature relative to the mid-channel value, and its length (denoted by T_c) represents the rise in coolant temperature from channel mid-point to outlet, or half the difference of the inlet and outlet temperatures. CF is a vector representing the temperature rise from coolant to can surface, which is proportional to the local fuel rating. Consequently CF is in phase with the vector OB which represents the local fuel rating. The length of CF, denoted by T_{sc}, corresponds to the maximum value of the temperature rise from coolant to can surface, which can be calculated from a knowledge of the heat transfer coefficient and the mid-channel fuel rating.

It will be appreciated that the rise in gas temperature in passing through the channel is governed by the total heat generation in the channel, including heat liberated in the moderator, so that the magnitude of the vector OC is dependent on this quantity, whereas the vector CF, representing the can-to-coolant temperature difference, has its

Vector Diagram for Reactor Channel Temperatures

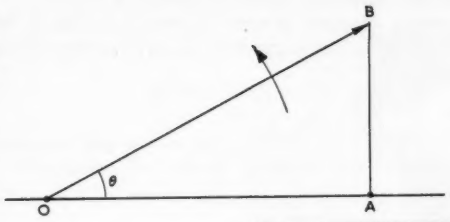


FIG. 1.

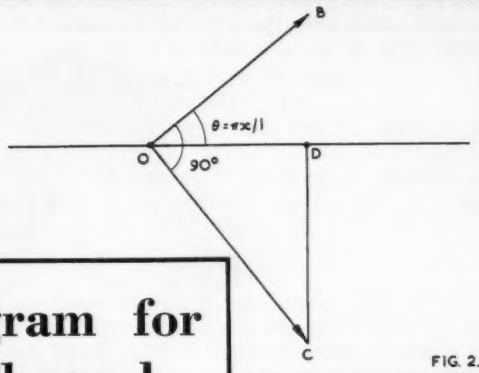


FIG. 2.

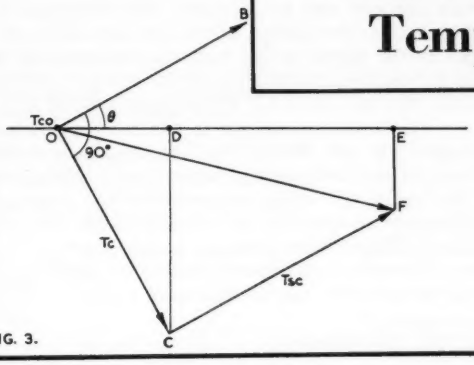


FIG. 3.

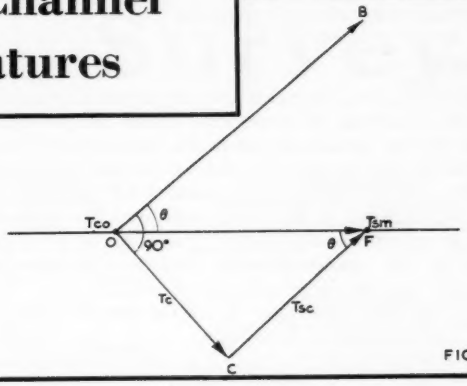


FIG. 4.

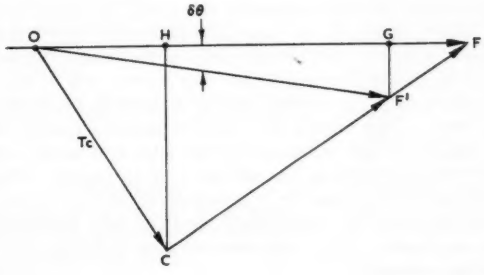


FIG. 5.

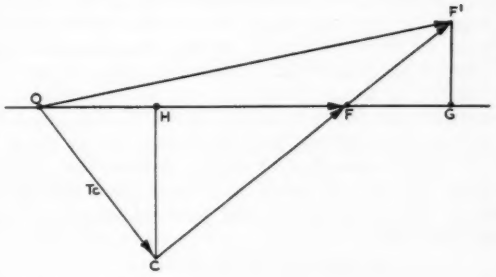


FIG. 6.

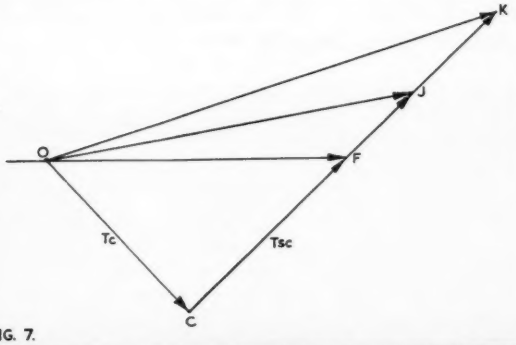


FIG. 7.

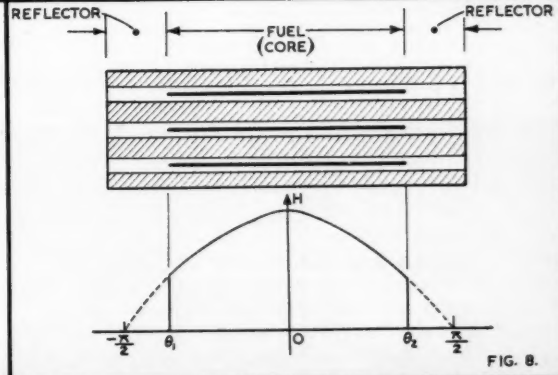


FIG. 8.

magnitude determined by the net heat generation in the fuel only.

From Fig. 3, it is evident that the maximum can surface temperature occurs when the vector OF coincides with the initial line (Fig. 4), i.e., at a value of x such that:

$$\tan\theta = OC/CF = T_c/T_{sc} = (T_2-T_1)/2\,T_{sc},$$

where T_1 and T_2 are the coolant inlet and outlet temperatures.

The difference between the maximum can surface temperature, T_{sm}, and the mid-channel coolant temperature, T_{co}, is given by the length of the vector OF; thus:

$$T_{sm}-T_{co} = (T_c^2+T_{sc}^2)^{1/2} = ((T_2-T_1)^2/4+T_{sc}^2)^{1/2}$$

Of course, these results can be derived easily without the use of a vector diagram, but it is often helpful to have such a diagram in mind, particularly when minor changes to the channel design are under consideration, and a rapid assessment of their effects is required.

Applications

(1) An increase in channel heat-rating which is unaccompanied by a change in mass-flow, causes proportionate increases in the maximum can-to-gas temperature difference, and in the temperature rise of the gas from inlet to outlet. The corresponding vectors CF and OC in Fig. 4 are increased in the same ratio, and the shape of the vector triangle is unchanged. The position along the channel of the can-temperature maximum is therefore unchanged, but the value of $(T_{sm}-T_{co})$ increases in proportion to the channel rating. It follows that the value of $(T_{sm}-T_1)$ increases in the same ratio.

(2) If, with the channel rating and mass flow held constant, the fuel cans are changed so as to increase the heat transfer coefficient, the gas-temperature vector OC remains unchanged, but the can-to-gas temperature vector, CF, is shortened, as shown in Fig. 5, so that the point F moves to F′, where the ratio CF/CF′ equals the ratio of the new heat-transfer coefficient to the old one, say $(1+k):1$.

The maximum can temperature, given by the length of OF′, is less than before, and the change in its value is given to a good approximation by the distance GF. As the projection HF of CF gives the can-to-gas temperature difference, say T, at the original point of maximum can temperature, and

$$GF/HF = F'F/CF = k/(1+k)$$

it follows that the reduction in T_{sm} is equal to $Tk/(1+k)$, which may be approximated by Tk for the small changes that usually come under consideration. It is apparent that T is given by:

$$HF = FC^2/OF = T_c^2/(T_{sm}-T_{co}).$$

The shift in position of the can-temperature vector from OF to OF′ shows that the maximum can temperature now occurs farther along the channel than before, the change in its position being given by δx where $\delta\theta = \pi\delta x/l$, and also:

$$\delta\theta \simeq GF'/OF' = (GF'/GF)\times(GF/OF') = (OC/CF)\times(GF/OF') = (T_c/T_{sc})\times(-\delta T_{sm})/(T_{sm}'-T_{co})$$

(3) If the channel heat rating and the mass flow are both increased by a factor $(1+f)$ without changing the can, the gas temperatures are unchanged, but the can-to-gas temperature difference increases, because the heat transfer coefficient does not increase quite in proportion to the mass flow. If the heat transfer coefficient is assumed to vary as (mass flow)$^{0.8}$ the combined effect of the increase in heat rating and in heat transfer coefficient is to increase the can-to-gas temperature difference in the ratio:

$$(1+f)/(1+f)^{0.8} = (1+f)^{0.2}$$

which is approximately equal to $1+0.2f$.

The vector diagram is now as shown in Fig. 6, where $FF'/CF = 0.2f$. The increase in T_{sm} is given approximately by FG;

$$FG = (FF'/CF)\times HF$$

so that $\delta T_{sm} = 0.2\,f\,T$,

where T signifies, as before, the can-to-gas temperature difference at the original point of maximum can temperature.

Fuel Centre and Surface Temperatures

The flow of heat radially outwards through the fuel and across the interface between the fuel and the can is accompanied by radial temperature drops, which are proportional to the local heat rating of the fuel, and vary along the channel in the same way as the temperature difference between the can and the coolant. The temperature rise from the can to the surface of the fuel, and from the fuel surface to the centre of the fuel, can therefore be represented by vectors such as FJ and JK in Fig. 7, which are in phase with the vector CF which represents the temperature rise (T_{sc}) from the coolant to the can. Consequently the vectors OJ and OK in Fig. 7 represent the values of the fuel surface and centre temperatures. These vectors lead the vector OF which represents the can temperature, and illustrate the fact that the maxima of the fuel surface and centre temperatures occur at points which are nearer to the inlet end of the channel than is the point at which the can temperature has its maximum value.

Core with End Reflectors

If the reactor core is surrounded by a neutron reflector, as is usual, the distribution of heat generation along the channel is still approximately sinusoidal in form; however, as shown in Fig. 8, the local heat generation in the fuel (H) does not tend to zero at the ends of the core. This means that the angle θ in Fig. 1 can take values only in the range from θ_1 to θ_2, as shown in Fig. 8, instead of from $-\pi/2$ to $+\pi/2$. The values of θ_1 and θ_2 depend mainly on the thickness of the reflectors at the inlet and outlet ends of the core, and will be known for a given design. They are not necessarily equal in magnitude, so that in general the reference point $\theta=O$, at which the local heat generation has its maximum value, does not coincide with the mid-point of the channel.

In these circumstances, consideration of Fig. 3 shows that the coolant temperature at the inlet end of the channel is given by:

$$T_1 = T_{co}+T_c\sin\theta_1,$$

and the value at the outlet end is given by:

$$T_2 = T_{co}+T_c\sin\theta_2,$$

where T_{co} is now taken to denote the coolant temperature at the point $\theta=O$.

Thus $T_c = (T_2-T_1)/(\sin\theta_2-\sin\theta_1)$

which reduces to

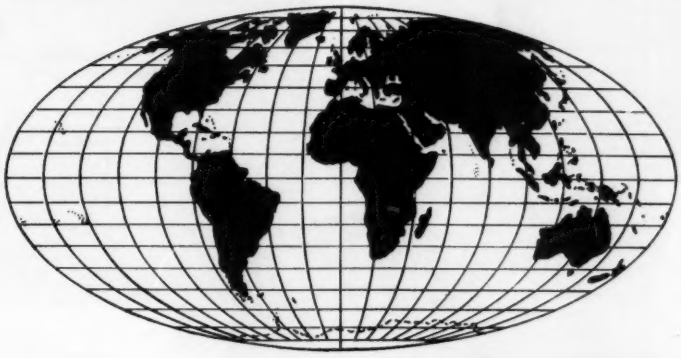
$$T_c = (T_2-T_1)/2$$

for the case where $\theta_1 = -\pi/2$ and $\theta_2 = +\pi/2$ corresponding to a bare reactor. Vector diagrams can now be drawn as before, with the proviso that T_{co} is no longer the mean of the coolant inlet and outlet temperatures, but is equal to $T_1-T_c\sin\theta_1$.

ACKNOWLEDGMENT

The author wishes to thank the management of the AEI-John Thompson Nuclear Energy Co., Ltd., for permission to publish this work.

World



Survey

Brief details of the important nuclear energy developments throughout the world with addresses of State authorities, principal officials and organizations, and notes on reactors in operation or under construction.

Argentina

COMMISSION NATIONALE A L'ENERGIE ATOMIQUE
8250 Av. Libertador General San Martin, Buenos Aires.

Reactors:
RA 1 An Argonaut-type reactor built and operated by CNEA. A second similar type, RA 2, is planned.

Australia

AUSTRALIAN ATOMIC ENERGY COMMISSION
45 Beach Street, Coogee, New South Wales.
Tel.: ME 1221.
T.A.: ATOMCOM, Sydney.
Chairman: Prof. P. Baxter.
Deputy Chairman: Dr. H. G. Raggatt.
Executive Commissioner: Mr. A. D. McKnight.
Commission Members: Prof. Sir Leslie Martin, Mr. H. M. Murray.
Reactors:
HIFAR, 10-MW DIDO type at Lucas Heights, commissioned on April 18, 1958. (Head Wrightson Processes.)

Austria

GOVERNMENT ADVISORY COMMISSION FOR PEACEFUL USES OF ATOMIC ENERGY
c/o Federal Ministry of Foreign Affairs, Ballhausplatz 2, Vienna 1.
Tel.: 635631.
T.A.: Aussenamt Wien.
Chairman: Dr. Heinrich Haymerle.
Reactors:
5-12 MW swimming pool tank-type for the Austrian Study Co. for Atomic Energy (AMF). 100 kW TRIGA for the Ministry of Education under construction. (General Dynamics.)

Belgian Congo

BELGIAN CONGO GOVERNMENT
Leopoldville, Belgian Congo.
Reactors:
10 kW TRIGA at the University of Lovanium, Leopoldville, first operated at Geneva in 1958 and restarted in Leopoldville in June, 1959. (General Dynamics.)

Belgium

COMMISSARIAT A L'ENERGIE ATOMIQUE
Rue de Louvain, No. 5, Bruxelles.
Tel.: 112350.
Commissaire: J. Errera.
Principal concerns:
Commission Nationale pour l'Etude de l'Utilisation Pacifique de l'Energie Nucleaire, 23 Square de Meeus, Bruxelles.
Centre d'Etude de l'Energie Nucleaire, Rue Belliard, 31, Bruxelles.
Institut Interuniversitaires des Sciences Nucleaires, Rue d'Egmont, 11, Bruxelles.
Groupement Professionnel de l'Industrie Nucleaire, 4, Rue de la Chancellerie, Bruxelles.
Reactors:
BR 1, 5MW natural uranium, air-cooled, graphite-moderated, commissioned on May 10, 1956.
BR 2, 50 MW, using enriched uranium, water moderated and cooled, under construction. (Nuclear Development Corp.)
BR 3, 11.5 MW pressurized water type (Westinghouse), test core went critical in U.S.A. in 1959.

Brazil

NATIONAL NUCLEAR ENERGY COMMISSION
350 Avenida Marechal Camera, Rio de Janeiro.
Chairman: Admiral Octalilio Cunha.
Reactors:
5 MW pool-type at Sao Paulo University went critical in 1957 (Babcock and Wilcox, U.S.A.).
30 kW TRIGA ordered for University of Minas Gerais. (General Dynamics.)

Bulgaria

INSTITUTE OF NUCLEAR PHYSICS
Academy of Science, Sofia.
Director: Prof. G. Manadjakov.
Reactors: 2-MW reactor using water cooling, built by the U.S.S.R.

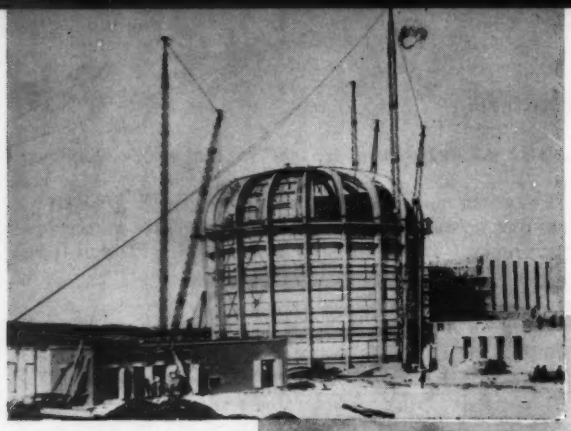
Burma

UNION OF BURMA ATOMIC ENERGY CENTRE
Kanbe, Rangoon.
Tel.: 30167.
T.A.: Uburatence.
Director: HLA Nyunt.
Divisional Heads: Soe Win, Cho Cho.

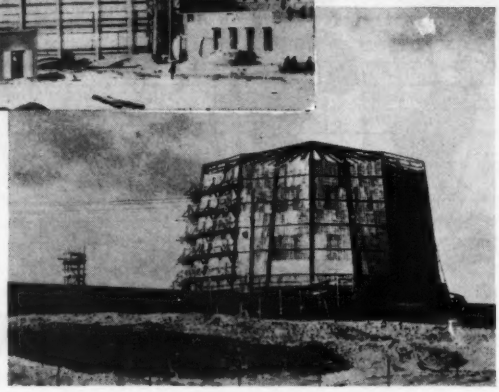
Canada

ATOMIC ENERGY OF CANADA, LIMITED
P.O. Box 711, Ottawa, Canada.
T.A.: " MOTA."
President: J. L. Gray.
Vice-president: W. B. Lewis (Research and Development).
Scientific Adviser to the President: D. A. Leys.
Treasurer: G. H. Sprague.
Secretary: D. Watson.
Research laboratories:
Nuclear Power Plant Division, P.O. Box 905, Toronto; Research Laboratories, Chalk River, Ontario; Commercial Products Division, P.O. Box 93, Ottawa.
Reactor design organizations:
Civilian Atomic Power Department, Canadian General Electric, 107 Park Street North, Peterborough, Ontario. Canadian Westinghouse, P.O. Box 510, Hamilton, Ontario.
Reactors:
ZEEP, zero energy; NRX 40 MW, D.O moderated, went critical in 1947; NRU 200 MW, D.O moderated and cooled, went critical in 1957; PTR, pool type; Chalk River.

The CERN headquarters in Geneva where the 25 GeV proton synchrotron is now in operation.



(1) Left. The Netherlands nuclear centre at Petten containing the 20 MW HFR type reactor.



(2) Right. The Israeli nuclear research centre near Tel-Aviv where a 1 to 5 MW pool-type reactor is under construction.

Canada (contd.)

D_2O moderated sub-critical assembly, University of Toronto, went critical in March, 1958.

1 MW pool type, McMaster University, went critical in April, 1959.

ZED 2 D_2O moderated zero energy at Chalk River.

NPD 20 MW moderated and cooled with D_2O under construction at Rolphton.

CANDU, 200 MW moderated and cooled with chosen D_2O under construction at Kincardine.

CERN

CERN, EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
Meyrin, Geneve 23 (Switzerland).
Tel.: 34 20 50.
T.A.: Cernlab—Geneve.
Council President: M. François de Rose (France).
Council Vice-presidents: Prof. W. Heisenberg (German Federal Republic); M. J. Willems (Belgium).
Committee Chairmen: Scientific Policy: Prof. E. Amaldi (Italy). Finance: M. J. H. Bannier (Netherlands).

The organization is mainly concerned with fundamental research on high energy particles. A 600-MeV synchro-cyclotron came into operation in 1958 and a 25-GeV alternating gradient proton synchrotron began operating in November, 1959.

China

ACADEMICA SINICA
3 Wen Tsin Chien, Peking.
Reactors:
2-MW swimming-pool type supplied by the U.S.S.R.
7-MW heavy-water type built with Soviet assistance.
A small research reactor is believed to be installed at the Nankai University, Tientsin.
A 60-MW power station is believed to be under construction.

Colombo

INSTITUTO DE ASUNTOS NUCLEARES
Avenida Aeropuerto, Internacional. El Dorado.
Tel.: 44-08-09.
Chairman: T. A. Marulanda.

Cuba

COMISION DE ENERGIA NUCLEAR DE CUBA
Paseo de Marti 212, Apartado 2471, Havana.
Reactors:
20 MW boiling-water type believed to be ordered from AMF for the National Bank for Social and Economic Development.

Czechoslovakia

ATOMIC ENERGY COMMISSION
Opletalova 23, Prague 3.
Reactors:
2 MW swimming-pool type built by the U.S.S.R. which went critical in September, 1957.
150 MW heavy-water type power station is reputed to be under construction at Bohunice, Bratislava.

Denmark

ATOMIC ENERGY COMMISSION
Christiansborg, Copenhagen K.
Tel.: Minerva 5433.
T.A.: Atomkom.
Director-general: Prof. T. Bjerge, Mr. Chr. L. Thomsen.
Vice-chairman: Mr. H. P. Christensen.
Principal concerns: Danatom, Strandvej, 102, Hellerup.
Reactors:
DR1 500 homogeneous solution type, went critical in August, 1957 (Atomics International).
DR 2 5 MW light water tank type, went critical in December, 1958 (Foster Wheeler).
DR 3 10 MW PLUTO type using heavy water moderator; diverged Jan. 17, 1960. (Head Wrightson.)

Dominican Republic

COMMISSION NACIONALE DE INVESTIGACIONES ATOMICAS,
Apartado 232, Ciudad Trujillo.
Tel.: 94472.

Egypt

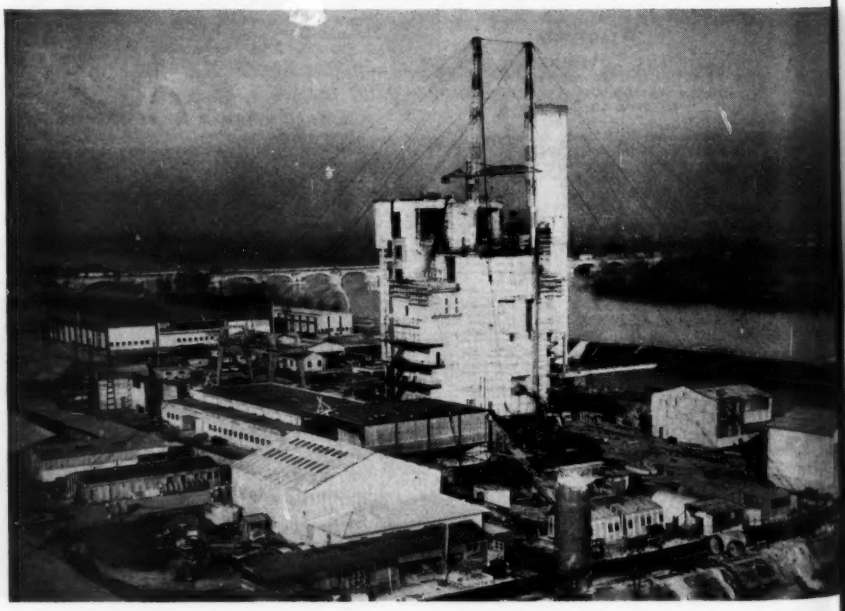
ATOMIC ENERGY COMMISSION
National Research Centre, Dokki, Cairo.
Tel.: 804930.
Reactors:
2-MW pool type supplied by the U.S.S.R.

Euratom

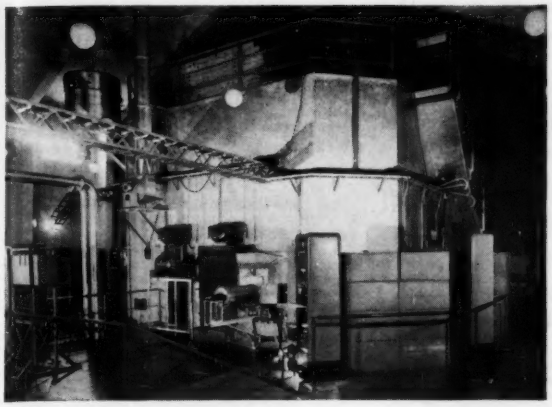
EUROPEAN ATOMIC ENERGY COMMUNITY (EURATOM)
51-3 rue Belliard, Brussels.
Tel.: 13, 40, 90.
President: Etienne Hirsch (Fr.).
Vice-president: Enrico Medi (It.).
Commission Members:
P. H. de Groot (Bel.), H. Krekeler (Ger.), E. M. J. Sassen (Neth). EURATOM came into existence on January 1, 1958 for the purpose of establishing a common market for nuclear projects between its member states. Agreements have been signed with OEEC, U.S., U.K. and Canada for the building of nuclear power stations and establishing joint research projects.
Member States:
Belgium, France, West Germany, Italy, Netherlands and Luxembourg.

France

COMMISSARIAT A L'ENERGIE ATOMIQUE,
69 Rue de Varenne, Paris VII.
Tel.: Invalides 6645.
T.A.: Energet-Paris.
High Commissioner: M. Francis Perrin.
Administrator General: M. Pierre Couture.
Principal officers:
M. H. Piatier; M. B. Goldschmidt; M. J. Renou; M. J. Asty; M. G. Charpentier; M. G. Bardet; M. J. Auzouy; M. J. Mabile; M. P. Taranger; M. A. Buchalet; M. J. Debiesse; M. H. Buissas; M. L. Neel; M. J. Yvon; M. R. Maillet; M. M. Surdin; M. C. Frejacques; M. M. Salesse.
Principal concerns:
CEA establishments:
Centre d'Etudes Nucleaires de Fontenay-Aux-Roses, Boite Postale 2, Fontenay-Aux-Roses (Seine); Centre d'Etudes Nucleaires de Saclay, B.P. 2, Gif-Sur-Yvette; Centre d'Etudes Nucleaires, Grenoble, B.P. 269, Grenoble; Centre de Production de Plutonium de Marcoule, Chusclan; Auxi-Atome, 11 rue de la Pepiniere, Paris; C.A.R.A., 45 Avenue Kleber, Paris, Compagnie Francaise des Minerais d'Uranium, 6 Avenue Gourgaud, Paris; Conservatome, 18 rue Seguin, Lyon; France-Atome, 6 Boulevard Haussman, Paris; Indatom, 48 rue de la Boetie, Paris; Société Centrale de l'Uranium et Minerais et Metaux Radioactifs, 4 Boulevard Trudaine, Clermont Ferrand, Puy de Dome; Société Intertechnique, 94 Avenue de Paris, Versailles; Société pour les Applications Techniques dans le Domaine de l'Energie Nucleaire, 45 Boulevard de la Gare, Paris, Dynatom, a company formed recently to collaborate with Atomics International in the construction of organic moderated reactors.



The first French nuclear power station at Chinon. The 60 MW station is expected to begin operating this year.



The Hungarian 2 MW tank type research reactor which began operating last year.

France (contd.)

Reactors:

EL 1, 150 kW gas-cooled, graphite-moderated type at Fontenay-Aux-Roses, went critical in 1948.

EL 2, 2 MW natural uranium, heavy water type at Saclay, went critical in 1952.

EL 3, 15 MW enriched uranium heavy water type at Saclay, went critical in 1957.

ALIZE, swimming pool type under construction at Saclay (Caratom).

1 MW pool type, TRITON, at Fontenay-Aux-Roses, went critical in 1959 (Indatom).

1 MW swimming pool type, Melusine, at Grenoble, went critical in 1959 (Indatom).

G 1, 5 MW(e) gas cooled, graphite moderated type at Marcoule, went critical in 1956.

G 2 and G 3, 28 MW(e), identical gas cooled, graphite moderated types at Marcoule, went critical in 1958 and 1959.

MARIUS, natural uranium, graphite moderated type at Marcoule.

EDF 1, 60 MW gas cooled, graphite moderated type at Chinon, still under construction.

EDF 2, 195 MW gas cooled graphite moderated type at Chinon, still under construction.

10 MW fast breeder type, Rapsodie, at Cadarache, still under construction.

10-17 MW beryllium oxide type, Brenda, planned for Cadarache.

PEGASE, light water type at Cadarache.

Finland

ATOMIC ENERGY COMMISSION
Ministry of Commerce and Industry, Hallituskatu 4, Helsinki.

Tel.: 14311.
Chairman: Prof. E. Laurila.
Principal concern:
Nuclear Power Association, c/o Ekono, Etela-Esplanaadikatu 14, Helsinki.
Reactors:
100 kW TRIGA Mk. II being planned for construction at the Institute of Technology, Helsinki (General Dynamics).

Germany, East

NUCLEAR RESEARCH INSTITUTE,
Neubrandenburg, Mecklenburg, Dresden.
Reactors:
2 MW water moderated type, near Dresden, went critical December, 1957, built by the U.S.S.R.
70 MW pressurized water power station, is reputed to be nearing completion at Neu Globsow, near Gransee.

Germany, West

BUNDESMINSTERIUM FUR ATOMKERN-ENERGIE UND WASSERWIRTSCHAFT
Bad Godesberg, Luisenstrasse 46.

Tel.: 5891-96.
T.A.: 8/85443.
Chairman: Prof. Dr.-Ing. Siegried Balke.
Secretary: Dr. Wolfgang Cartellieri.
Vice-chairmen: Prof. Dr. Leo Brandt, Prof. Dr. Otto Hahn, Prof. Dr.-Ing. Karl Winnacker.
Principal concerns:
Brown, Boverie A.G., Mannheim; Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt, Hamburg; Interatom, Hamburg· Siemens Schuckertwerke A.G., Erlangen; Rheinisch-Westfalische-Elekritzitatswerk A.G. (RWE); Degussa A.G., Frankfurt; Krupp, Essen; Farbwerke Hochst A.G., Frankfurt; Kernreaktor Bau und Betriebs Gesellschaft, Karlsruhe.
Reactors: Completed research reactors:
1 MW swimming pool type at Munich, went critical on October 31, 1957, operated by Land Bayern (AMF).
50 kW solution type at Frankfurt, went critical January 10, 1958, operated by Land Hessen (A.I.).
50 kW solution type at Berlin, went critical July 24, 1958, operated by Senat Berlin (A.I.).
5 MW swimming pool type at Hamburg, went critical October 22, 1958, operated by Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt (Babcock and Wilcox, U.S.A.).
Research reactors under construction:
12 MW heavy water type, FR 2 at Karlsruhe, expected to operate in 1961, built and operated by Kernreaktor Bau und Betriebs.
5 MW swimming pool type, MERLIN at Jülich, expected to operate in 1961, to be operated by Land Nordrhein-Westfalen (A.E.I.-John Thompson).
10 MW heavy water type, DIDO, Jülich, expected to operate 1961/2, to be operated by Land Nordrhein Westfalen (Head Wrightson, in conjunction with German firms).
Power-research reactors:
15 MW boiling water type, Kahl/Main, expected to operate this year, to be operated by RWE, Frankfurt (General Electric, U.S.A., AEG, Germany).
15 MW high temperature type at Jülich, construction expected to start this year, to be operated by AVR Dusseldorf (BBC Mannheim/Krupp).
160 MW OMR at a site in South-west Germany, was planned by Interatom for AKS Stuttgart. It was originally to be built under the U.S.-Euratom agreement but this is now not expected to be agreed.
10 kW Argonaut type, went critical June 23, 1959, Munich (SSW, Erlangen).
Power projects planned:
100 MW natural uranium type for the Gesellschaft für die Entwicklung der Stomkraft in Bayern, Munich (SSW, Erlangen).
100 MW boiling water type, for the Studiengesellschaft für Kernkraftwerke, Hanover (AEG, Frankfurt).
100 MW Calder type for the Studiengesellschaft für Kernkraftwerke, Hanover (Babcock and Wilcox).
Ship power projects planned:
10,000 S.H.P. OMR type for the Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt, Hamburg (Interatom).
20,000 S.H.P. boiling water type for Deutsche Werft Hamburg and AEG.
20,000 S.H.P. pressurized water type for Howaldtswerke, Hamburg and SSW, Erlangen.

Greece

ATOMIC ENERGY COMMISSION
Merlin 5, Athens, Greece.

Tel.: 616876.
T.A.: Greekatom.
Chairman: A. Spandis.
Vice-chairman: J. Pantazis.
Secretary: Th. G. Kouyoumzelis.
Reactors:
1 MW pool type under construction (AMF).

Greenland

A 1.5 MW power producing reactor is to be built by the United States to provide power for a new scientific base, Camp Century, now being built 100 miles inland, east of the coastal base at Thule.

Hungary

ORSZAGOS ATOMENERGIA BIZOTTSAG (NATIONAL ATOMIC ENERGY COMMISSION)
Budapest 57, Hungary.

Tel.: 115-434.
Chairman: Antal Apro.
Vice-chairmen: Arpad Kiss, Lajos Janossy.
Secretary: Mihaly Kokeny.
Reactors:
2 MW tank type built by the U.S.S.R. and commissioned in December, 1959.

I.A.E.A.

INTERNATIONAL ATOMIC ENERGY AGENCY
Kärntnerring 11, Vienna 1, Austria.
Director-general: Mr. W. Sterling Cole.
Board of Governors: A rotation of representatives of the 70 member states.
Programme:
To aid and develop the application of the peaceful uses of nuclear energy.

Iceland

ICELAND NUCLEAR SCIENCE COMMISSION
Laugavegur 118, Reykjavik, Iceland.
Chairman: Prof. Thorbjorn Sigurgeirsson.
Vice-chairman: Mr. Jakob Gislaon.
Director-general: Mr. Magnus Magnusson.

India

ATOMIC ENERGY COMMISSION
Apollo Pier Road, Bombay, 1.

Tel.: Bombay 253904.
T.A.: ATOMERG—BOMBAY.
Chairman: Dr. H. J. Bhabha.
Member for Finance and Administration: Mr. P. N. Thapar.
Member: Dr. K. S. Krishnan.
Reactors:
100 kW swimming pool type at Trombay went critical in August, 1956.
100 kW TRIGA Mk II at the World Agricultural Fair, New Delhi, began operating December, 1959 (General Dynamics).
40 MW Canada-India type of NRX expected to go critical this year.
Zero energy heavy water type, Zerlina, still under construction.

Iran

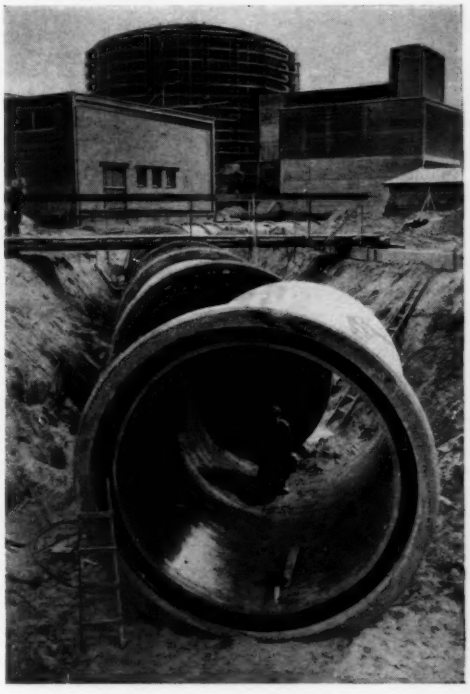
CENTO INSTITUTE OF NUCLEAR SCIENCE
P.O. Box 1828, Tehran.

Reactors:
5 MW pool type under construction at the University of Tehran (AMF).

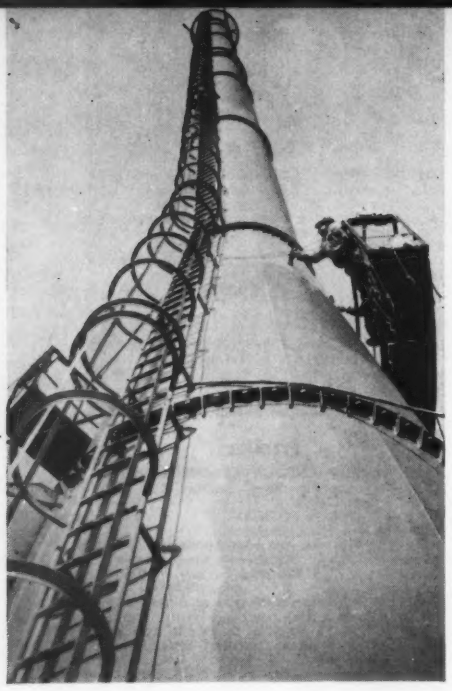
Israel

ATOMIC ENERGY COMMISSION
P.O. Box 7055, Hakirya, Tel-Aviv.

Tel.: Tel-Aviv 29268.
Chairman: Dr. Ernst David Bergmann.
Members: Dr. Israel Dostrovsky, General Jacob Dori, Dr. Saul Cohen, Prof. Joel Rakah, Prof. Samuel Sambursky.
Reactors:
1-5 MW pool type (AMF) expected to go critical mid-1960.



The West German research centre under construction at Karlsruhe.



The 250 ft high chimney at the Italian research centre at Ispra. Plans have been made to turn the centre into a Euratom facility.

Italy

COMITATO NAZIONALE PER LE RICERCHE NUCLEARI
Via Belisario 15, Rome.
Tel.: Rome 460900.
T.A.: NucLeare Rome.
President: Prof. B. Focaccia.
Vice-presidents: Prof. E. Amaldi, Prof. A. Angelini.
Secretary: Prof. F. Ippolito.
Principal Organizations:
Agip-Nucleare, Via Passarella 2, Milan; SENN, Via Savoia 15, Rome; SELNI, Via Foro Buonaparte 31, Milan; SORIN, Via Turati 8, Milan.
Reactors:
5 MW CP-5 type at Varese. (A.C.F. and Vitro Engineering.)
5 MW swimming pool type, Avogadro RS-1, at Saluggia. (Fiat, Montecatini.)
200 MW gas-cooled graphite moderated power station under construction at Latina. (Agip-Nucleare, Nuclear Power Plant, U.K.)
150 MW boiling water type power station under construction at Punta Fiume, near Naples. Rating now being reconsidered. (SENN, General Electric.)
160 MW pressurized water power station to be constructed at a site near Milan by SELNI. The World Bank have granted a loan of $40m. towards this project.
Zero energy type at University of Palermo went critical in 1958. (Aerojet General Nuclear.)
5 MW heavy water tank type went critical at the Government Research Centre at Ispra in 1959. (Allis-Chalmers.)

General Franco at the 3 MW swimming pool reactor at Moncloa near Madrid.

1 MW pool type at the SORIN Research Centre went critical in 1959. (AMF.)
50 kW solution type at the Milan Technical University went critical in 1959. (Atomics International.)
100 kW TRIGA Mk II under construction at the National Committee for Nuclear Research Centre near Rome. (General Dynamics.)
5 MW pool type under construction at the Naval Academy and University of Pisa. (Babcock and Wilcox.)

Japan

ATOMIC ENERGY COMMISSION
2-2 Chome Kasumigaseki, Chiyoda-ku, Tokyo.
Chairman: Rt. Hon. Mr. Y. Nakasone.
Vice-chairman: Mr. I. Ishikawa.
Director-general: Mr. Y. Sasaki.
Principal concerns:
Mitsubishi Atomic Power, Higashi 9, 2 Marunouchi, Chiyoda-ku, Tokyo; First Atomic Power Industrial Group, 1 Ote-Machi, Chiyoda-ku, Tokyo; Nippon Atomic Energy Industrial Group, Daiichi-Bussan, 1 Tamuracho, Siba, Tokyo; Sumitomo Atomic Energy Commission, 5 Kitahama, Higashi-ku, Osaka; Atomic Industrial Conference, 1 Marunouchi, Chiyoda-ku, Tokyo.
Reactors:
50 kW solution type at the Atomic Energy Research Institute, Tokai Mura went critical in August, 1958. (Atomics International.)
10 MW heavy-water type under construction at the Atomic Energy Research Institute at Tokai Mura. (AMF.)
Zero energy facility under construction at the Kinki University, Osaka. (American Radiator and Standard Sanitary.)
100 kW TRIGA Mk. II planned for St. Paul's University, Tokyo. (General Dynamics.)
100 kW TRIGA Mk. II planned for the Rikkyo University at Yokosuka City. (General Dynamics.)
100 kW TRIGA Mk. II type planned for Musashi Institute of Technology at Kawasaki. (General Dynamics.)
40 MW boiling-water power station under construction at Tokai Mura. (General Electric.)
150 MW gas cooled graphite moderated power station under construction, Tokai Mura. (G.E.C.)

J.I.N.R.

JOINT INSTITUTE OF NUCLEAR RESEARCH
Head Post Office, P.O. Box 79, Moscow.
Director: Prof. D. I. Blokhinstev (U.S.S.R.).
Vice-directors: Prof. Wang Kan-chang (China); Prof. E. Djakov (Bulgaria).
Member States:
Albania, Bulgaria, Czechoslovakia, Chinese People's Republic, Democratic Republic of Viet-Nam, German Democratic Republic, Hungary, Korean People's Republic, Mongolia, Poland, Rumania, U.S.S.R.

Korea

ATOMIC ENERGY COMMISSION
Korean Government, Seoul.
Reactors:
100 kW TRIGA Mk. II type planned to be built at Seoul. (General Dynamics.)

Mexico

COMISION NACIONAL DE ENERGIA NUCLEAR
Insurgentes Sur 1079, Mexico D.F.
Tel.: 236133.
T.A.: Nacnuclear.
Chairman: Dr. J. M. Ortiz-Tirado.
Vice-chairmen: Dr. M. Sandoval-Vallarta, Dr. N. Carrillo-Flores.
Secretary: Dr. Salvador Cardona.
Principal concern:
Dr. C. Velez Ocon, Comision Nacional de Electricidad, Insurgentes Sur 1079, Mexico D.F.

Netherlands

FOUNDATION REACTOR CENTRUM NEDERLAND
Scheveningseweg 112, The Hague, The Netherlands.
Tel.: The Hague 51481.
T.A.: Reactorholland.
Chairman: Dr. E. L. Kramer.
Vice-chairman: Mr. L. de Block.
Reactors:
100 kW swimming-pool type at Delft University (AMF), went critical May, 1957.
20 MW HFR-type at the research centre, Petten (Allis-Chalmers), expected to go critical in 1961.

New Zealand

NUCLEAR SCIENCES INSTITUTE
Department of Scientific and Industrial Research, Gracefield, Lower Hutt, New Zealand.
Tel.: 69-199.
T.A.: Research, Wellington.
Chairman: Dr. R. W. Harman.
Vice-chairman: Dr. G. A. Currie.
Director: T. A. Rafer.

Norway

INSTITUTT FOR ATOMENERGI
Postbox 175, Lillestrøm.
Tel.: 71 25 60.
T.A.: Atomenergi, Oslo.
Chairman: Dr. Carl Høegh.
Vice-chairman: Prof. Bjørn Trumpy.
Director-general: Mr. Gunnar Randers.
Principal concerns: Noratom A/S, Oslo.
Reactors:
450 kW natural uranium, JEEP type at Kjeller, went critical July 30, 1951.
10 MW Halden boiling heavy water at Kjeller, under the OEEC joint research programme, went critical June 29, 1959.
Zero energy facility (Noratom) at Kjeller, expected to go critical in 1961.

OEEC

OEEC EUROPEAN NUCLEAR ENERGY AGENCY
38 Boulevard Suchet, Paris XVI.
Tel.: Tro 46-10, 74-30, 76-00.

STEERING COMMITTEE
Chairman: Prof. Leandre Nicolaidis (Greece).
Vice-chairmen: M. Pierre Couture (France); Mr. F. F. Turnbull (U.K.).

SECRETARIAT
Director: M. Pierre Huet (France).
Scientific Adviser: Dr. Lew Kowarski (France).
Deputy Director: Mr. Einar Saeland (Norway).

CO-OPERATION IN THE REACTOR FIELD
Chairman: Prof. Francis Perrin (France).
Vice-chairman: Sir John Cockcroft (U.K.).

STUDY GROUP, EXPERIMENTAL REACTORS
Chairman: Dr. Sigvard Eklund (Sweden).
Vice-chairman: Prof. Serigo Gallone (Italy).

HEAVY WATER PRODUCTION
Chairman: Dr. C. W. Hart-Jones (U.K.).

NUCLEAR DATA
Chairman: Dr. E. Bretscher (U.K.).

HEALTH AND SAFETY SUB-COMMITTEE
Chairman: Dr. S. Halter (Belgium).

WORKING PARTY ON TRAINING
Chairman: Mr. Robert Major (Norway).

THIRD-PARTY LIABILITY
Chairman: M. Adrian D. Belinfante (Netherlands).
Vice-chairmen: Prof. Dr. Otto Kaufmann (Switzerland); Mr. J. P. H. Trevor (U.K.).

JOINT WORKING PARTY ON INTERNATIONAL TRADE
Chairman: M. M. Heimo (Switzerland).

EUROCHEMIC PROJECT
Chairman: Mr. Erik Svenke (Sweden).
Vice-chairman: Dr. Bertrand Goldschmidt (France).
Managing Director: Dr. Erich Pohland.
Scientific and Technical Committee
Chairman: M. Yves Sousselier (France).
Project, to build, at Mol (Belgium) a plant and laboratories for the chemical processing of irradiated nuclear fuels and for the extraction of plutonium. The installations will be used both to develop fuel-processing techniques and for the training of specialists in this field.
Countries taking part:
Austria, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and Turkey.

HALDEN PROJECT COMMITTEE
Chairman: Dr. Jules Guéron (Euratom).

TECHNICAL GROUP
Chairman: Mr. G. Holte (Sweden).
Project Manager (Institutt for Atomenergi): Mr. O. R. Kasa (Norway).
Programme of research and experiment with the Norwegian boiling heavy water reactor (maximum power 20 MW(t) at Halden, south of Oslo.
Countries taking part:
Norway, Austria, Denmark, Euratom, Sweden, Switzerland and the U.K.

Pakistan

PAKISTAN ATOMIC ENERGY COMMISSION
Government of Pakistan, Victoria Road, Preedy Street Corner, Karachi.
T.A.: "Atomcom" Karachi
Chairman: Dr. Nazir Ahmed
Commission members: Dr. Riazuddin Siddiqui. Dr. O. M. Ghani.
Reactors:
1 MW pool type planned for construction at Taxila (AMF).

Philippines

PHILIPPINE ATOMIC ENERGY COMMISSION
727 Herran Street, Manila, Philippines.
Tel.: 51814.
T.A.: Philatomic, Manila.
Commissioner: Col. F. A. Medina.
Deputy Commissioner: Mr. P. G. Afable.
Reactors:
1 MW swimming pool type under construction (General Electric) expected to go critical mid-1961.

Poland

ATOMIC ENERGY COMMISSION
(Biuro Pelnomocnika Razadu dla Spraw Wykorzystania Energii Jadrowej)
Palac Kultury i Nauki, Warszawa, Poland
Tel.: 69531.
Chairman: W. Bilig.
Vice-chairman: J. Metera.
Reactors:
2 MW swimming pool type, EWA, at the Nuclear Research Institute, near Warsaw, went critical in 1959.

Portugal

JUNTA DA ENERGIA NUCLEAR
Rua de S. Pedro de Alcantara 79, Lisboa, Portugal.
Tel.: 36.88.56.
Chairman: Eng. José Frederico Ulrich.
Reactors:
1 MW pool type still under construction near Lisbon (AMF).

Puerto Rico

A joint proposal between the U.S. AEC and the Puerto Rico Water Resources Authority calls for the establishment of a 16 MW boiling-water type plant producing superheated steam within the core. The Water Resources Authority will operate and maintain the plant on a reimbursable basis.

Rumania

INSTUTUL PENTRU ENERGIA NUCLEARA AL ACADEMIEI
Calea Victorie 125, Bucharest.
Reactors:
A 2 kW enriched uranium water moderated type supplied by the U.S.S.R.

South Africa

ATOMIC ENERGY BOARD OF SOUTH AFRICA
Merino Buildings, Pretorius Street, Pretoria.
Tel.: Pretoria 22540.
T.A.: Isotope Pretoria.
Chairman: Senator the Hon. J. de Klerk.
Deputy-chairman: Dr. T. E. W. Schumann.
Research Director: Dr. A. J. A. Roux.
Chief Scientists: Dr. M. G. M. Atmore; Dr. L. J. le Roux; Dr. W. L. Grant.
Assistant Chief Scientist: Dr. S. J. du Toit.
Principal concerns:
Uranium Production Committee, Government Offices, P.O. Box 1132, Johannesburg. Council for Scientific and Industrial Research, P.O. Box 395, Pretoria.
Reactors:
A 5 MW reactor will be purchased abroad and a 10 MW will be constructed at the new research centre to be built near Pretoria.

Spain

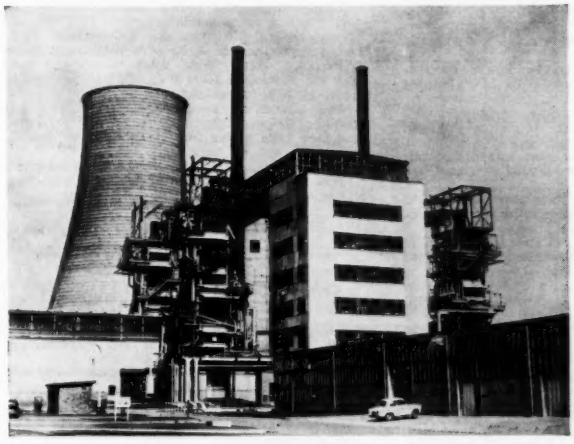
JUNTA DE ENERGIA NUCLEAR
Serrano 121, Madrid, Spain.
Tel.: 34-54-05.
Chairman: Sr. D. José María Otero Navascués.
Reactors:
3 MW pool type near Madrid went critical in 1958 (General Electric, U.S.).

Sweden

STATENS RAD FOR ATOMFORSKNING
Dobelnsgatan 641, Stockholm Va.
Tel.: 32 08 16.
Chairman: Governor Mats Lemne.
Vice-chairman: Prof. Torsten Gustafson.
Director-general: Dr. Gosta W. Funke.
Principal concerns:
AB Atomenergi, Liljeholmen, Stockholm.
ASEA, Vasteras.
Vattenfallsstyrelsen (State Power Board), Karduansmakaregatan 8, Stockholm.
Atomkraftkonsortiet (AKK), Stureplan 19, Stockholm.
Sveriges Mekanforbund (Association of Swedish Mechanical Industries), Malmtorgsgatan 10, Stockholm.
Reactors:
R1 300 kW heavy-water type at Liljeholmen AB Atomenergi, went critical in 1954.
R2 30 MW high-flux type at the Studsvik research centre (Allis-Chalmers), expected to go critical in 1960.
R3/Adam 65 MW pressurized heavy-water type to be constructed at Agesta, near Stockholm, by ASEA. It is expected to go critical in 1962 and the containment space in solid rock is under construction.
R4/Eve 100 MW pressurized heavy-water type has been planned and will be constructed somewhere in central Sweden.

Switzerland

THE DELEGATE ON MATTERS OF ATOMIC ENERGY
55 Effingerstrasse, Berne, Switzerland.
Tel.: 61 50 54 58.
Delegate: Dr. Jakob C. Burckhardt.
Deputy-delegate: Dr. Wilhelm Schilling.
Principal concerns:
Reaktor AG, Wurenlingen.
Konsortium für den Bau eines Versuchs-Atomkraftwerks, Gebruder Sulzer AG, Winterthur.
Energie Nucleaire SA, 10 Avenue de la Gare, Lausanne.
Suistatom AG, Bahnhofplatz 3, Zurich.
Atomelektra AG, Talacker 16, Zurich.
Brown, Boveri AG, Baden/Aargau.
Reactors:
1 MW swimming-pool type at Wurenlingen (Reaktor AG, and AEC), went critical May, 1957.
12.5 MW heavy-water type at Wurenlingen (Reaktor AG), due to go critical this month.
20 W AGN 201 at the University of Geneva (Aerojet-General Nucleonics), went critical in December, 1958.
100 W AGN at the University of Basle (Aerojet-General Nucleonics), went critical June, 1959.
Design and experimental work has been done on two BWR prototype power reactors. One a 5 MW type, is to be built at Luceny by Energie Nucleare SA, and the other, a 16 MW, at Zurich (Suisatom) by a Swiss consortium.



Chapelcross, the second nuclear power station in the U.K. which began operating last year. It is now supplying 140 MW to the national grid.

Taiwan

THE ATOMIC ENERGY COUNCIL
c/o Ministry of Education, Taipeh (Taiwan).
Reactors:
1 MW pool type under construction at Hainchu. (General Electric, U.S.)

Thailand

MINISTRY OF COMMUNICATIONS
Bangkok, Thailand.
Reactors:
1 MW pool type under construction at Chulalongkhorn University. (Curtiss-Wright.)

Turkey

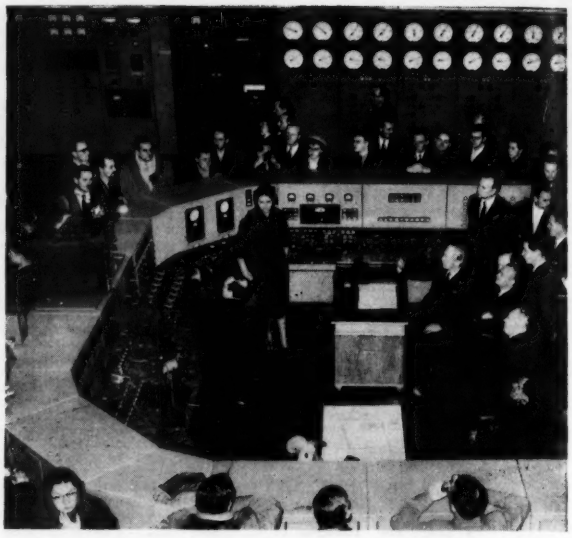
ATOMIC ENERGY COMMISSION
Genel Sekreterligi, Etibank, Ankara, Turkey.
Tel.: 19377 Ankara.
Chairman: Adnan Menderes, The Prime Minister, represented by Fatin Rustu Zorlu, the Minister of Foreign Affairs.
Secretary-general: Dr. Nuri Refet Korur.
Reactors:
1 MW swimming pool type near Istanbul (AMF), went critical May, 1959.

United Kingdom

UNITED KINGDOM ATOMIC ENERGY AUTHORITY
11 Charles II Street, London, S.W.1.
Tel.: Whitehall 6262.
T.A.: U.Katen London Telex.
Chairman: Sir Roger Makins.
Member for development and engineering: Sir William Cook.
Member for external relations and commercial policy: Sir Alan Hitchman.
Member for production: Sir Leonard Owen.
Member for weapons research: Sir Claude Pelly.
Member for scientific research: Sir William Penney.
Member for finance and administration: Sir Donald Perrott.
Part-time members:
Sir James Chadwick; Rt. Hon. Lord Citrine; Sir John Cockcroft; Mr. C. F. Kearton; Sir Rowland Smith; Sir Ivan Stedeford.
Nuclear power stations completed:
Calder Hall, 140 MW gas cooled, graphite moderated commissioned 1956 and 1958.
Chapelcross, 140 MW gas cooled, graphite moderated, commissioned 1959.
Nuclear stations under construction:
Berkeley, 275 MW gas cooled, graphite moderated, expected to begin operating mid-1961. (AEI-John Thompson.)
Bradwell, 300 MW gas cooled, graphite moderated, expected to begin operating mid-1961. (Nuclear Power Plant.)
Hinkley Point, 500 MW gas cooled, graphite moderated, expected to begin operating mid-1962. (English Electric-Babcock and Wilcox-Taylor Woodrow.)
Trawsfynydd, 500 MW gas cooled, graphite moderated, expected to begin operating 1964. (APC.)
Nuclear power stations planned:
Dungeness, 550 MW gas cooled, graphite moderated, still under tender.
Sizewell, 650 MW gas cooled, graphite moderated, still under tender.
Oldbury, 1,000 MW gas cooled, graphite moderated, possibly AGR.
AEA research reactors:
GLEEP, 100 kW air-cooled type at Harwell, went critical in 1947.
BEPO, 6 MW air-cooled type at Harwell, went critical in 1948.
DIMPLE, 100 W heavy-water type at Harwell, went critical in 1954.
LIDO, 100 kW light-water type at Harwell, went critical in 1956.
DIDO, 10 MW heavy-water type at Harwell, went critical in 1956.
NERO, 100 W graphite-moderated type at Harwell, went critical in 1957.
PLUTO, 10 MW heavy-water type at Harwell, went critical in 1957.
NEPTUNE, 100 W light-water type at Harwell, went critical in 1957.
DMTR, 10 MW Pluto heavy-water type at Dounreay, went critical in 1958.
HORACE, 10 W light-water type at Aldermaston, went critical in 1958.
Fast breeder, 60 MW type at Dounreay, went critical in 1959.
HERALD, 5 MW light-water type at Aldermaston, expected critical in the spring, 1960.
ZENITH, 100 W gas-cooled type at Winfrith, went critical in 1959.
AGR, 100 MW advanced gas-cooled type at Windscale, expected to go critical in 1961.
HERO, low-power graphite-moderated type at Windscale, expected to go critical in 1961.
NESTOR, 10 kW JASON type at Winfrith, expected to go critical in 1960.
Principal concerns:
See Buyers' Guide facing page 144.

U.S.A.

U.S. ATOMIC ENERGY COMMISSION
Washington, D.C.
Tel.: Hazelwood 7-7831.
Chairman: John A. McCone.
Commission Members: Mr. J. F. Floberg; Mrs. J. S. Graham; Dr. J. H. Williams.
Principal concerns:
Allis-Chalmers; ACF Industries; Aerojet-General Corp.; Aerojet-General Nucleonics; Alco Products; AMF Atomics; American Radiator and Standard; Babcock and Wilcox; Bendix Aviation; Bethlehem Shipbuilding; Combustion Engineering; Nucledyne Corp.; Daystrom, Inc.; E. I. de Pont de Nemours; Foster Wheeler Corp.; Flour Corporation; General Dynamics; General Electric; General Nuclear; H. K. Ferguson; Ingalls Shipbuilding; Kaiser Engineers; Lockheed Aircraft; Mare Island Naval Shipyard; Martin Co.; Atomics International; Newport News Shipbuilding; Nuclear Development; Portsmouth Naval Shipyard; Phillips Petroleum; Pratt & Whitney Aircraft; Sandia Corp.; Westinghouse Electric; Vitro Engineering.
National Laboratories:
Los Alamos Scientific Laboratory; Argonne National Laboratory; Oak Ridge National Laboratory; Brookhaven National Laboratory; Radiation Laboratory, Berkeley and Livermore.
Power stations built, building or planned:
Shippingport Atomic Powers Station 60 MW pressurized-water type at Shippingport, went critical in 1957. (Westinghouse.)
Commonwealth Edison's Dresden Nuclear Power Station, 180 MW boiling-water type at Morris, Illinois, went critical in 1959. (General Electric.)
Consolidated Edison Thorium Reactor, 255 MW pressurized-water type, under construction at Indian Point, N.Y. (Babcock and Wilcox.)
Enrico Fermi Atomic Power Plant, 94 MW fast breeder under contruction at Lagoona Beach, Mich. (Power Reactor Development.)
Yankee Atomic Electric have under construction a 110 MW pressurized-water type at Rowe, Mass. (Westinghouse.)
AEC and Rural Co-operative Power Association have under construction a 22 MW boiling-water type at Elk River, Minn. (Allis-Chalmers.)
Hallam Nuclear Power Facility, Sheldon Station, a 75 MW sodium-graphite type at Hallam, Nebraska. (Atomics International.)
AEC and City of Piqua have under construction an 11.4 MW organic-moderated type in Ohio. (Atomics International.)
Northern States Power, Pathfinder Plant, a 62 MW boiling-water type planned for Sioux Falls, S. Dakota. (Allis-Chalmers.)
Carolina-Virginia Nuclear Power Associates, a 17 MW pressure-tube, heavy-water type, planned for Parr, S.C. (Westinghouse.)
Humboldt Bay Powerplant, a 47.5 MW boiling-water type planned for Humboldt Bay, Calif. (General Electric.)
Consumers Power, a 50 MW boiling-water type for Big Rock Point, Mich. (General Electric.)
Small Size Nuclear Powerplant, a 22 MW pressurized-water type.
East Central and Florida West Nuclear Groups, a 50 MW gas-cooled, heavy-water, moderated type at Florida. (General Nuclear.)
Philadelphia Electric, a 28.5 MW gas-cooled, graphite-moderated type at Peach Bottom, Pa. (General Dynamics.)
Other AEC proposals are:
A 50 MW improved-cycle, boiling-water type.
16.3 MW boiling reactor nuclear superheat.
50 MW organic-cooled type.

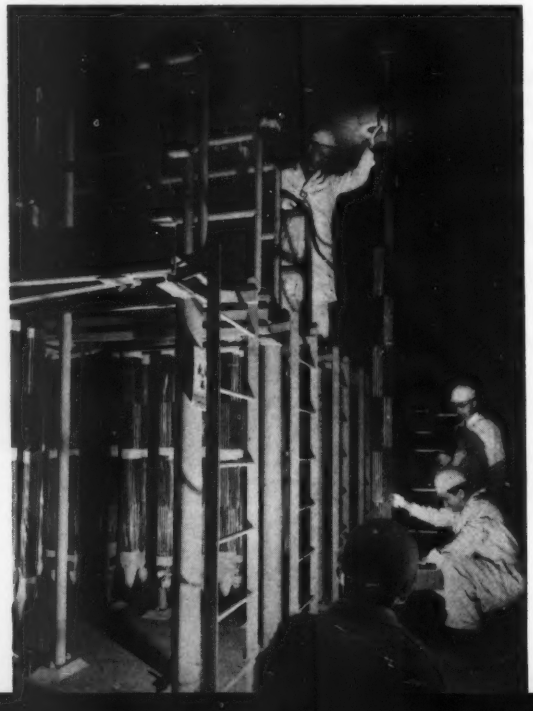


The control room of the nuclear research centre at Dubna, U.S.S.R.

There are 19 other civilian reactor experiments built, building or planned.
One civilian ship is under construction, *N.S. Savannah* powered by a 22 MW pressurized-water type reactor (New York Shipbuilding) and two more are planned; a 30 MW light water-type tanker and a 22 MW gas-cooled type.
Nine submarines using nuclear propulsion are operating, 28 are under construction and a further four have been authorized. It is believed that 75 submarines will be built.
165 research, test and material production reactors are built, building or planned, excluding critical facilities, in the U.S.A.

U.S.S.R.

CENTRAL BOARD FOR THE USE OF ATOMIC ENERGY
Moscow, U.S.S.R.
Reactors:
ITR, 2 MW pool type at the Academy of Sciences, went critical in 1957.
TR, 2.5 MW heavy water type at the Institute of Heat Technology, Moscow.
Portable 2 MW pressurized water type at Obinsk, went critical in 1959.
WWR, 2 MW tank type near Leningrad, went critical in 1959.
BR 1, fast breeder type, went critical in 1955.
BR 2, 100 kW fast breeder type, went critical in 1956.
BR 5, 5 MW fast breeder type, went critical in 1958.
35 MW homogeneous type under construction at Ulyavonsk.
15-20 MW graphite moderated type at the Institute of Physics, Moscow, went critical in 1952.
10 MW water-water type at the Physical and Technical Institute in Leningrad has been completed.
Intermediate energy type using beryllium oxide believed to be under construction.
Power stations:
APS, 5 MW natural uranium water-cooled type at Obinsk, went critical in 1954.
600 MW natural uranium, graphite moderated, water-cooled type at Trotsk in Siberia, partly operating (1958).
Two 100 MW water cooled graphite moderated types at Beloyarsle in the Urals, under construction.
50 MW boiling water type under construction at Ulyanovsk.
210 MW pressurized water type under construction at Voronezh.
BR 50, 50 MW fast breeder type under construction at Ulyanovsk.
Ships:
The ice breaker *Lenin*, powered by three pressurized water type reactors, is now operating with the Soviet merchant fleet. No details of submarines are available but at least three are believed to be completed, or under construction.



Fuel elements for Dresden, Commonwealth Edison's 180 MW boiling water power station which began operating last year.

Venezuela

INSTITUTO VENEZUELA DE INVESTIGACIONES CIENTIFICES
Iviv, Apartado 1827, Caracas.
Tel.: 719224.
T.A.: IVIC, Caracas.
Director: Dr. M. Roche.
Reactors:
3 MW swimming pool type still under construction. (General Electric.)

Vietnam

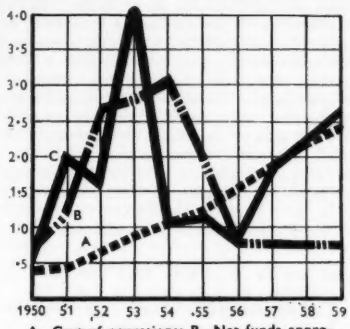
GOVERNMENT OF VIETNAM
Dalat, Vietnam.
Reactors:
100 kW TRIGA Mk. II under construction at Dalat. (General Dynamics.)

Yugoslavia

NUCLEAR ENERGY COMMISSION
P.O. Box 353, Belgrade.
President: Mr. A. Rankovic.
Principal concerns:
Bureau for Nuclear Raw Materials, Nemaniina 5, Belgrade; Institute of Nuclear Sciencies, "Boris Kidric," Vinca, Belgrade.
Reactors:
Zero energy, natural uranium heavy water moderated type at the Boris Kidric Institute went critical in 1958.
10 MW heavy water graphite reflected type at the Boris Kidric Institute went critical in 1959.

U.S. Development Costs

The U.S. AEC's annual report for June 30, 1958—June 30, 1959 has now been published. In it the work of the Commission is reviewed and an account given of the present status of their programme together with a review of current and past expenditure. We reproduce the tables of experimental and special reactors now in operation, under construction or planned, together with curves showing the trends in expenditure over the past few years.



A—Cost of operations; B—Net funds appropriated; C—Plant and equipment expenditure. Figures expressed in $1,000 million.

Budget Estimates for 1961

The U.S. AEC has called for an operating budget for 1961 of $2,427 million, an increase of some $40 million over the previous year. The total includes approximately $570 million for special materials, $495 million for weapons, $436 million for reactor development, $159 million for physical research, $54 million for biology and medicine, $12¼ million for isotope applications and commercial uses of nuclear explosives and $55 million for administration. Under reactor development is included over $8 million for merchant ship reactors plus nearly $3 million for operating expenses of the "Savannah," $73 million for aircraft propulsion, $14 million for satellite power sources, $8 million for army power reactors and $85 million for naval propulsion.

The construction budget of the U.S. AEC for 1961 is $215 million, including over $100 million for reactor development and nearly $57 million for special materials; weapons building is estimated at $27½ million. Research and development total for 1961 is over $1,000 million—$47 million higher than the previous year's figure.

Industry's Nuclear Sales

The U.S. Department of Commerce have completed their report on Atomic Energy Products Shipments for 1958 (Form MA-38Q). This shows that during that year the manufacturing value to industry of key nuclear energy products totalled nearly $150 million. This figure is made up of $24 million for radiation detection and monitoring devices; $17 million for reactor vessels and tanks; $15 million for accessory instrumentation for reactor controls; $24 million for reactor fuel elements for shipment directly for use or installation in a reactor; $13.8 million, heat exchangers; $11.4 million, valves; $9.5 million, pumps; these last three concern equipment specifically designed for nuclear applications. Reactors completely assembled at the place of manufacture were valued at $1.2 million.

	Research and Development Costs*			Construction Costs		
	Cumulative Through June 30, 1959	Fiscal Year 1959	Fiscal Year 1958	Costs Through June 30 1959	Additional Construction Authorized	Total
	$ M.	$ M.	$ M.	$ M.	$ M.	$ M.
Civilian Nuclear Power Reactors						
Pressurized light water	102.9	26.1	17.3	49.2	15.8	65.0
Boiling light water	29.3	5.9	4.4	3.0	12.0	15.0
Heavy water	18.5	10.8	5.9	11.5	18.9	30.4
Organic moderated	15.5	6.1	5.5	1.1	13.9	15.0
Gas cooled	13.3	9.5	3.8	—	30.0	30.0
Sodium cooled	43.1	15.5	11.6	3.2	25.5	28.7
Fluid fuel	92.9	21.6	22.7	3.3	0.8	4.1
Fast breeder	40.5	8.8	6.8	13.5	20.0	33.5
Other development	1.9	1.0	0.7	2.4	30.2	32.6
Total	357.9	105.3	78.7	87.2	167.1	254.3
Army Reactors						
Pressurized water	4.5	1.7	0.7	1.7	7.9	9.6
Boiling water	2.4	0.8	0.6	1.6	0.4	2.0
Gas cooled	12.1	6.4	4.1	0.4	2.1	2.5
Other development	1.3	0.5	0.3	0.2	0.8	1.0
Total	20.3	9.4	5.7	3.9	11.2	15.1
Merchant Ship Reactors	7.2	4.7	1.5	8.7	17.6	26.3
Aircraft Reactors						
Manned aircraft :						
Direct cycle	177.8	50.3	43.4	29.1	20.4	49.5
Liquid cycle	133.9	17.0	17.5	0.9	—	0.9
Other development	19.9	4.5	5.1	5.5	—	5.5
Missile propulsion :						
Rocket (Project Rover)	33.6	14.0	8.2	14.9	15.9	30.8
Ramjet (Project Pluto)	18.6	8.8	4.3	3.2	9.3	12.5
Auxiliary power sources	12.9	7.7	3.4	0.4	1.9	2.3
Total	396.7	102.3	81.9	54.0	47.5	101.5
Naval reactors						
Submarines	296.0	35.6	44.9	128.9	1.3	130.2
Large ship prototype	96.6	25.9	29.7	33.3	1.7	35.0
Guided missile cruiser	9.1	3.0	4.3	—	—	—
Destroyer prototype	22.8	13.4	7.8	9.4	26.3	35.7
Other development	43.5	12.7	10.6	6.5	1.3	7.8
Total	468.0	90.6	97.3	178.1	30.6	208.7
General	376.9	43.3	41.1	†266.0	57.7	323.7
Total reactor development costs	1,627.0	355.6	306.2	597.9	331.7	929.6

* Includes depreciation. † Includes equipment.

REACTOR EXPERIMENTS

Designation	Location	Principal nuclear contractor	Type	Power (kW)		Start-up
				Electrical (net)	Thermal	
EBR–1	NRTS, Idaho	ANL	Fast Breeder	150	1,400	1951
EBWR	Lemont, Ill.	ANL	Boiling water	4,500	100,000	1956
VBWR	Pleasanton, Calif.	GE	Boiling water	5,000	30,000	1957
SRE	Santa Susana, Calif.	AI	Sodium graphite	6,000	20,000	1957
OMRE	NRTS, Idaho	AI	Organic moderated	—	5,000–15,000	1957
HRE–2	Oak Ridge, Tenn.	ORNL	Aqueous homogeneous solution.	Negligible	5,220	1957
EBR–2	NRTS, Idaho	ANL	Fast breeder	16,500	62,500	1961
LAMPRE	Los Alamos, N. Mex.	LASL	Fast molten plutonium fuelled, sodium cooled.	—	1,000	1959
BORAX–5	NRTS, Idaho	ANL	Light water	2,000	20,000	1961
—	Saxton, Pa	West	Pressurized water	5,000	—	1961
TURRET	Los Alamos, N. Mex.	LASL	Gas cooled	—	3,000	1962
EGCR	Oak Ridge, Tenn.	KE–ACF	Gas cooled graphite moderated.	22,300	84,300	1962
EOCR	NRTS, Idaho	—	Organic	—	40,000	—
ELPHR	Point Loma, San Diego, Calif.	—	Pressurized water	SL	40,000	1962

PROTOTYPES, EXPERIMENTS AND FIELD PLANTS

Designation	Location	Principal contractor	Type	Power (net kW(e))	Start-up
S1W	NRTS, Idaho	West	Pressurized water	—	1953
SM–1	Ft. Belvoir, Va	Alco	Pressurized water	1,855	1957
A1W	NRTS, Idaho	West	Pressurized water	—	1958
S3G	West Milton, N.Y.	GE	Pressurized water	—	1958
SL–1	NRTS, Idaho	ANL	Boiling water	200	1958
KIWI–A	NTS Nevada	LASL	Open cycle gas	—	1959
HTRE–1 and 2	NRTS, Idaho	GE	—	—	—
HTRE–3	NRTS, Idaho	GE	—	—	—
S1C	Windsor, Conn.	CE	Pressurized water	—	1959
SER	Santa Susana, Calif.	AI	—	—	—
GCRE–1	NRTS, Idaho	AG	Gas cooled	—	1959
D1G	West Milton, N.Y.	GE	Pressurized water	—	—
SM–1A	Fort Greely, Alaska	Alco	Pressurized water	1,700	1960
PM–1	Sundance, Wyo.	Martin	Pressurized water	1,000	1961
PM–2A	Arctic Location	Alco	Pressurized water	1,500	1961
ML–1	NRTS, Idaho	AG	Gas cooled	400	1961

TRANSLATIONS

Résumés of Principal Articles

Prix de Revient du Courant Produit Dans Les Réacteurs Type Calder Hall (*page* 95)

Des rapports officieux semblent indiquer que le prix de revient du courant produit par la première centrale atomique civile britannique sera plus élevé que prévu initialement. Nuclear Engineering *a examiné ces rapports et conclut que, des éléments dont on ne tient pas compte habituellement dans l'analyse des résultats d'exploitation des centrales thermiques conventionnelles ont été pris en considération. Les fabricants de matériel ont été priés de bien vouloir indiquer leurs meilleures conditions et le commissariat à l'énergie atomique ses plus récents prix d'éléments de combustible. On en conclut, qu'en Angleterre, les futures controles atomiques de grande puissance devraient permettre de produire de l'énergie électrique au prix de 0.55d le kWh (0.04 NF/kWh) alors que pour des centrales similaires construites dans d'autres pays où le faux d'intérêt est plus élevé, le prix devrait se situer dans l'intervalle 8 mill/kWh—10 mill/kWh (0.04NF/kWh—0.05 NF/kWh).*

Precautions a Prendre Pour L'Utilisation des Réacteurs de Recherche de Faible Puissance (*page* 96)

L'intérêt dont on fait preuve actuellement pour les réacteurs de recherche de faible puissance rend urgente l'énonciation des principes de sécurité qui dovient être appliqués lors de l'opération de réacteurs de ce type. Il est suggéré que la réactivité du système doit être telle qu'il n'y ait aucun danger résultant d'un saut de réactivité ou d'un accroissement linéaire de réactivité accidentels. En outre le refroidissement des éléments de combustible doit être suffisant.

Les Réacteurs de Recherche (*page* 99)

Durant les deux dernières années un nombre considérable de réacteurs de recherche ont été lancés sur le marché mondial. Les modéles disponibles vont du petit réacteur d'un milliwat destiné à l'entraînement de personnel jusqu'au réacteur de recherche de puissance élevée ou destiné à l'essai des matériaux. Seules les installations commercialisées constituant un ensemble sont décrites (et non les installations construites " sur mesure ").

Les Besoins Universitaires en Matière de Réacteurs de Recherche (*page* 105)

Une série d'articles explicite les principales caractéristiques exigées des réacteurs de recherche ou décrit la façon dont sont utilisées les installations existantes. Les professeurs Hall et Murgatroyd analysent les buts que se sont fixés les universités anglaises où l'on met surtout l'accent sur la recherche dans le domaine du génie nucléaire. Il n'est pas rentable de construire un réacteur pour les seuls besoins de l'enseignement. Les professeurs Maier-Leibnitz et Soutif décrivent les installations respectives dont ils disposent et qui comportent principalement des réacteurs d'une puissance nominale de 1MW du type piscine. Les dispositifs expérimentaux qui se trouvent le plus près des parois sont les plus utilisés et des flux neutroniques élevés, supérieurs à $10^{13} n/cm^2$ sec sont jugés indispensables.

Le professeur Sellschop analyse les facteurs favorables à une installation de grande puissance devant permettre de centraliser diverses recherches dans un domaine étendu. Cette installation sera vraisemblablement la principale du genre en Afrique du Sud.

Die Kosten gasgekühlter und-moderierter Atomkraftwerke (Seite 95)

Berichte, die unbestätigt blieben, besagten, dass die Kosten des ersten britischen Atomkraftwerkes für allgemeine Zwecke viel höher sein würden, als man ursprünglich angenommen hatte. Nuclear Engineering *ist diesen Berichten nachgegangen und hat gefunden, dass die Kosten nicht mit Werken, die mit Kohlenfeuerung arbeiten, ohne weiteres verglichen werden können, weil bei den Atomkraftwerken Kosten mit einbegriffen sind, die normalerweise bei Werken, die mit fossilem Brennmaterial arbeiten, nicht mitgerechnet werden. Die Fabriken sind um ihre neuesten Ziffern die Kapitalkosten betreffend befragt worden, und die AEA um ihre neuesten Preise für Brennstoffelemente. Es wurde daraus geschlossen, dass bei den späteren grossen Kraftwerken in Grossbritannien die Krafterzeugungskosten 0,55 d je kW-Stunde betragen werden, während bei solchen Werken in Uebersee, wo höhere Zinssätze eingerechnet werden müssen, die Kosten im Bereich von 8 mils je kW-Stunde und 10 mils je kW-Stunde für ein einzelnes Atomkraftwerk liegen werden.*

Sicherheitsregeln für Forschungs-Reaktoren geringer Leistung (Seite 96)

Das zur Zeit vorhandene Interesse in Forschungs-Reaktoren mit niedriger Leistung lässt vermuten, dass die Aufstellung von Regeln, die für Sicherheit dieser Klasse von Reaktoren gelten, an der Zeit ist. Es wird angenommen, dass die überschüssige Reaktivität des Systems eine solche nur sein darf, dass keine zufällige plötzliche oder allmähliche Aenderung der Reaktivität Anlass zu einer gefährlichen Erhöhung geben kann.

Forschungs-Reaktoren (Seite 99)

Eine beträchtliche Zahl von Forschungs-Reaktoren ist während der letzten beiden Jahren auf dem Weltmarkt erschienen. Ihre Grössen gehen vom kleinen Milliwatt Reaktor für Uebungszwecke bis zum Hochleistungs-Forschungs- und Untersuchungs-Reaktor. Nur die Anlagen, die als komplette Einheiten (im Gegensatz zu solchen, die vom Kunden entworfen sind) auf den Markt gebracht werden, sind aufgenommen.

Forschungs-Reaktoren und die Erfordernisse für Universitäten (Seite 105)

Die Artikelreihe bringt Einzelheiten über die Erfordernisse von Universitäten und erläutert die Zwecke, für die vorhandenen Reaktor-Forschungseinrichtungen Verwendung gefunden haben. Die Professoren Hall und Murgatroyd stellen Betrachtungen an über die Erfordernisse an britischen Universitäten, wo die Forschung sich in der Hauptsache mit den technischen Anwendungen der Atomkraft befasst.

Professor Maier-Leibnitz und Professor Soutif besprechen ihre Experimente mit dem 1 MW (nominell) Schwimmbad-Reaktor. Vorrichtungen in nächster Nähe der Wandung werden am meisten verlangt, und ein hoher Neutronenfluss von über $10^{13} n/cm^2$ sec wird für wichtig gehalten.

Professor Sellschop befasst sich mit den Elementen zugunsten von Einrichtungen mit höherer Leistung, die notwendig sind, um als Zentrum für einen weiten Bereich von verschiedenen Interessen zu dienen, und die voraussichtlich die Haupt-Forschungsstelle in der Südafrikanischen Union darstellen werden.

Costo de Potencia Moderada por Enfriamiento a Gas (pág. 95)

Noticias no confirmadas tienden a indicar que la potencia para la primera central generadora nuclear civil de la Gran Bretaña, habría de ser mucho mayor que lo anticipado originalmente. Nuclear Engineering *ha investigado estos informes y llega a la conclusión que, en comparación con las centrales alimentadas a carbón, se han incluido en la centrales nucleares costos que normalmente no se incluyen en las estaciones que consumen carbón fosilífero. Se ha rogado a los fabricantes que presentasen sus más recientes cifras de costo capital y a la AEA sus más recientes precios sobre elementos de combustible. Se llega a la conclusión que las grandes centrales del futuro en la Gran Bretaña tendrán un costo de generación de 0.55d. por kW/h mientras que las mismas centrales construidas en ultramar donde el tipo de interés es más alto, el costo estará en la región de 8 " mill " por kW/h y 10 " mill " por kW/h para centrales de un solo reactor.*

Principios de Seguridad para Reactores de Investigación de Baja Potencia (pág. 96)

El interés actual en reactores de investigación de baja potencia sugiere que es oportuno hacer una exposición de los principios fundamentales de este tipo de reactor. Se sugiere que el exceso de reactividad del sistema tiene que ser tal que ningún cambio de paso o de rampa pueda dar lugar a peligro. Además, el enfriamiento de los elementos de combustible deberá ser adecuado e inherente en el diseño para evitar cualquier falla o fusión peligrosa.

Reactores de Investigación (pág. 99)

En los dos últimos años se han puesto a la venta en el mercado mundial un número considerable de reactores para la investigación. Comprenden desde los reactores más pequeños en MW para fines de entrenamiento hasta los reactores de pruebas y altas potencias. Solamente se incluyen aquellas facilidades que se ofrecen al mercado como unidades completas (en contraposición a las diseñadas por el cliente).

Reactores de Investigación y las Necesidades Universitarias (pág. 105)

Una serie de artículos que detallan las necesidades de las universidades o explican el uso a que se han dedicado las actuales facilidades de los reactores de investigación. Los Profesores Hall y Murgatroyd analizan las necesidades de las universidades británicas en las cuales la necesidad predominante es la investigación de los problemas de la ingeniería nuclear. Un reactor no puede ser justificado para fines de enseñanza únicamente, sino que ha de servir también como una herramienta necesaria para el uso de estudiantes dedicados a la investigación.

El Profesor Maier-Leibnitz y el Profesor Soutif discuten sus experimentos con los reactores de piscina de 1 MW (nominal). Hay gran demanda por las facilidades más allegadas a la pared y se consideran indispensables los flujos de gran potencial neutrónico por encima de $10^{13} n/cm^2$ sec.

El Profesor Sellschop se ocupa de los elementos a favor de una facilidad de mayor potencia que es necesaria para actuar como centro de una gran variedad de actividades de investigación y el cual probablemente resulte la principal facilidad de investigación en la Unión Sud Africana.

Principaux Contrats en Cours (*page* 112)

Le commissariat britannique à l'énergie atomique (U.K. AEA) vient de publier les principaux chapitres de ses dépenses annuelles d'équipement spécialisé. A l'heure actuelle, il en ressort que 10–12 *millions de livres sont dépensées pour de l'équipement dont les prix sont fixés d'avance alors qu'environ* 5 *millions de livres sont dépensées pour des études et des recherches. Dans les années à venir les montants dépensés au type de ce dernier chapitre doubleront approximativement. En outre, et en plus des dépenses ci-dessus,* 30 *millions de livres au moins sont dépensées chaque année pour des travaux de génie civil ou pour la constitution de stocks de matières premières.*

L'énergie Nucléaire en Allemagne (*page* 113)

L'article fait le point du développement actuel de l'énergie nucléaire en Allemagne. L'auteur attribue à l'absence d'une législation spéciale et à la division de l'Allemagne en états confédéres, le lenteur du développement de l'énergie nucléaire dans ce pays. L'article montre que la compétition entre le gouvernement central et les gouvernements des Länder aura plutôt tendance à treiner les progrès, plutôt qu'à les stimuler. Le plan actuel prévoit une puissance installée de 500 *MW pour* 1965 *mais il ne semble pas que l'effort de recherche nécessaire pour la réalisation de ce programme soit apprécié pleinement.*

L'etude des Grillages Circulaires (*page* 116)

Le comportement d'un grillage à mailles carrées reposant sur un cylindre circulaire est analysé. Lorsque le grillage est composé de poutres uniformes supportee à leur extrémité sur le cylindre, les réactions tendent à être concentrées en certains points de la peripherie.

Pour parer à ces concentrations, deux methodes ont été étudieés. Dans la première ont utilisé des poutres à moment d'inertie variable. Dans la seconde méthode, le grillage se trouve en porte-à-foux sur un anneau de rigidité circulaire concentrique ou cylindre.

Un Diagramme Vectoriel pour les Températures de Canaux de Réacteurs (*page* 120)

Pour l'évaluation rapide des effets modifications de paramètres de dessins sur les températures du réfrigérant et du matériau de chemisage le long d'une section de canal on peut se servir d'un simple diagramme des vecteurs. En prenant la distribution d'écoulement axial comme fonction cosinus, on développe le diagramme complet pour une pile nue, le point central du canal servant d'origine. L'emploi du diagramme est démontré en variant trois facteurs l'un aprés l'autre.

Le diagramme des vecteurs est ensuite développé encore plus pour inclure des températures de combustible et les modifications nécessaires pour tenir compte des réflecteurs d'extrémité y sont expliquées. Une évaluation exacte des températures basée sur détails d'un dessin déterminé sera obtenue par calculs directs; la méthode décrite dans ses grandes lignes a sa valeur pour l'établissement des comparaisons.

Revue Mondiale (*page* 123)

Les principaux organismes gouvernementaux ainsi que les principaux groupes privés engagés dans la recherche et le génie nucléaire sont passés en revue. Une liste des installations qui ont été mises en service ces deux dernières années est donnée. Les principales caractéristiques de divers programmes de construction de centrales sont analysées. Il n'est pas possible d'inclure tous les détails relatifs au programme et aux principales organisations des Etats Unis, faute de place.

Die Kontrakte der AEA mit der Industrie (Seite 112)

Die britische Atombehörde (United Kingdom Atomic Energy Authority) hat in grossen Zügen Einzelheiten uber ihre jährlichen Ausgaben für spezielle Einrichtungen bekanntgemacht. Gegenwärtig entsprechen diese angenähert 10-12 *Millionen £ für Arbeiten, die Kontrakte für Einrichtungen zu festen Preisen umfassen, und rund* 5 *Millionen £ für Arbeiten, die im allgemeinen Kontrakte für Entwicklungsarbeiten betreffen. In den allernächsten Jahren wird sich diese Ziffer für Entwicklungsarbeiten ungefähr verdoppeln. Darüber hinaus werden Bauarbeiten, Lager und der Ankauf von Rohmaterial mindestens weitere* 30 *Millionen erfordern.*

Atomkraft-Technik in Deutschland (Seite 113)

Ein Bericht über den gegenwärtigen Stand der Entwicklung der Technik auf dem Gebiet der Atomkraft. Der Autor kommt zu dem Ergebnis, dass das Fehlen spezieller Gesetze sowohl, als auch die Wirkung des Foederalismus zu dem nur langsamen Fortschritt in der Entwicklung in Deutschland beigetragen haben. In dem Aufsatz wird die Vermutung ausgesprochen, dass der Wettbewerb zwischen den Regierungen der Länder und der Bundesregierung die Entwicklung eher hindert, als dass er sie fördert. Der gegenwärtige Bauplan hat einen Ausbau der Leistung zu 500 *MW für* 1965 *in Auge, jedoch ist es zweifelhaft, ob man die Grösse der notwendigen Entwicklungsarbeiten voll in Anschlag gebracht hat.*

Der Entwurf und die Berechnung kreisförmiger Rostkonstruktionen (Seite 116)

In dem Aufsatz wird das Verhalten eines Quadrat-Gitterrostes mit kreisförmigem Umfang auf einem Kreiszylinder-Untergestell analysiert. Es wird gezeigt, dass, wenn der Rost aus gleichförmigen Balken aufgebaut und der Umfang gleich dem des kreisförmigen Untergestells ist, die Reaktionen im Untergestell die Neigung haben, sich an Punkten zu konzentrieren, die auf dem Umfang im Winkel von 45° *zu den Achsen der Balken liegen. Zwei Methoden werden beschrieben, um diese Ungleichförmigkeit aufzuheben: Die erste Methode besteht darin, die Trägheit der Rostbalken zu variieren, die zweite Methode benutzt einen starren Balkenring als Kante, während der Rost auf Auslegern ruht, die den Gestell-Zylinder überragen.*

Vektor-Diagramm für die Temperatur in einem Reaktorkanal (Seite 120)

Um rasch die Wirkung von Aenderungen in den Konstruktions-Kennziffern auf die Temperatur von Kühlmittel und Mantel-Werkstoff für eine bestimmte Kanallänge abschätzen zu können, kann ein einfaches Vektor-Diagramm benutzt werden. Aus der achsialen Verteilung des Flusses als Kosinus-Funktion wird das vollständige Diagramm für einen Reaktor ohne Reflektor entwickelt, wobei als Nullpunkt der Mittelpunkt des Kanals gewählt wird. Wie das Diagramm zu benutzen ist, wird durch Variierung von drei Faktoren gezeigt.

Welt Ueberblick (Seite 123)

Dies ist ein Bericht über die bedeutenderen Regierungs-Organisationen und die wichtigsten Industrie-Gemeinschaften, die an der technischen Entwicklung der Atomkraft arbeiten. Der Bericht enthält Listen der bedeutenderen Anlagen, die in den letzten beiden Jahren in Betrieb genommen wurden, er gibt weiter die wesentlichen Punkte der vielen fertigen Pläne zur Krafterzeugung. Wegen des beschränkten Raumes ist es nicht möglich volle Einzelheiten des Programms und der Organisationen in den Vereinigten Staaten zu geben.

Contratos de la AEA con la Industria (pág. 112)

La Atomic Energy Authority (Autoridad de Energía Atómica) del Reino Unido ha dado a la publicidad detalles de sus gastos anuales en equipo especializado. En la actualidad esos gastos se elevan a £10/12 *millones en equipo cubierto por contratos a precio fijo y, alrededor de otros* £5 *millones en obras generalmente cubiertas por contratos de ampliación. En los próximos años la cifra por contratos de ampliación será probablemente duplicada. Además de esto, las cantidades empleadas en ingeniería civil, pertrechos y compras de materias primas se elevará probablemente a* £30 *millones, por lo menos.*

La Ingeniería Nuclear en Alemania (pág. 113)

Se pasa revista al estado actual de los desarrollos de la ingeniería nuclear en Alemania. El autor llega a la conclusión que la ausencia de leyes adecuadas y los efectos del federalismo han contribuido a retardar el avance en aquel país. El artículo sugiere que la rivalidad entre los Gobiernos provinciales y el Gobierno Federal tiende a dificultar y no a fomentar el desenvolvimiento. El actual plan industrial prevee una capacidad de 500 *MW instalada para* 1965, *pero es dudoso esto, si se tiene en cuenta debidamente el peso de desarrollo necesario.*

Diseño y Analisis de Emparrillados Circulares (pág. 116)

Este artículo se refiere al funcionamiento de un emparrillado de malla cuadriculada dentro de un borde circular, soportado por un cilindro circular. Se muestra que, cuando el emparrillado está compuesto de viguetas uniformes y el borde es además el círculo de apoyo, las reacciones de soporte tienden a concentrar en puntos del borde a 45° *de la dirección de las viguetas. Se describen dos métodos de vencer esta falta de uniformidad; el primero, significa variar la inercia de las viguetas que componen el emparrillado, mientras que el segundo se vale de una vigueta de borde de aro rígido, y el emparrillado es voladizo sobre su cilindro de apoyo.*

Un Diagrama Vectorial para Temperaturas en Canales de Reactores (pág. 120)

Para la evaluación rápida de los efectos de cambios en diseño de parámetros sobre las temperaturas de refrigerantes y material de enfundadora a lo largo de un trecho de canal, se puede emplear un simple diagrama vectorial. Tomando la distribución del flujo axial como función de coseno se desarrolla el diagrama completo para una pila desnuda, sirviendo de origen el punto medio del canal. El empleo del diagrama se demuestra variando tres factores en turno.

El diagrama Vectorial, se desarrolla aun más para incluir las temperaturas del combustible y las modificaciones necesarias para tomar en consideración los reflectores de extremo, también se explican. La evaluación exacta de las temperaturas sobre detalles de un diseño determinado se logran por medio de cálculos directos; el sistema bosquejado resulta valioso para hacer comparaciones.

Perspectiva Mundial (pág. 123)

Se hace un estudio de las organizaciones gubernamentales y de los principales equipos dedicados al equipos industriales desenvolvimiento de la energía nuclear. Se destacan las principales facilidades que han entrado en operación en los dos años pasados y se ofrece una descripción de muchos de los programas de energía ya establecidos. No es posible en el espacio disponible, incluir plenos detalles del programa de los Estados Unidos de Norte América y sus organizaciones.

Technical Papers and Publications

THE INSTITUTE OF MARINE ENGINEERS

(Joint Panel on Nuclear Marine Propulsion)

The Control and Instrumentation of a Marine Reactor. By R. Anscomb, O.B.E., and F. Hutber (D. and E. Group, U.K. AEA, Risley).

The main object of this paper was to give a general outline of the problems of control as they affected marine reactors, and to indicate possible solutions, and it was pointed out that, particularly with the more advanced types, the behaviour of reactors under transient conditions was not an exact science as yet.

The first portion of the paper was devoted to a general survey of reactor behaviour, and the effect on reactivity of delayed neutrons, temperature, voids in the moderator, and poisoning. The system was then discussed, not as a pure reactor, but as a power-producing system, considering the control problems from the standpoint of maintaining desired operating conditions, as well as from that of merely avoiding damage to the components. It was pointed out that there were two fundamental equations for the reactor itself; that co-relating thermal power with coolant mass flow and inlet and outlet temperatures, and that dealing with heat transfer from the fuel element. In a heat exchanger system there were heat transfer and heat balance equations for each section, thus giving a total of six further equations for a 3-section (economizer, evaporation, and superheat) exchanger.

Control programming required a selection of the properties which must be held constant, or varied deliberately, to suit the characteristics of a given reactor system, and every system had its own particular "musts." For example, while steady can surface temperatures were necessary for all types of reactor, and steady steam pressures were desirable for all power-producing units, primary coolant pressure could be varied independently in a gas-cooled reactor—or in a non-boiling liquid system—but was an integral parameter of boiling systems. Again, coolant outlet temperature might be a limiting feature of an organic moderated plant—quite independent of can temperature—due to the risk of pyrolytic breakdown of the moderator.

Typical control programmes were then considered for various systems. Considering non-boiling liquid systems, it was possible to aim at constant average coolant temperature, or constant outlet coolant temperature. The first had control advantages, and also kept a practically constant volume of coolant in the system, thus minimizing the size of the pressurizer. Both, however, had the handicap of permitting variations in steam pressure, with consequent effects on the design of turbine, pipework, feed pump, and dump condenser. The advantages of constant average temperature and constant steam pressure could be obtained by a compromise solution, but the control problems could become very complicated.

An additional complication in the case of organic moderated systems was, as previously mentioned, that the outlet temperature should be limited. A system was outlined, in which the coolant flow was maintained constant through the core, using a controlled by-pass line to vary the flow through the heat exchanger.

Boiling reactors tended to be limited in output by the maximum steam void fraction which could be tolerated for smooth operation, and the sudden increase in this by steam flashing when load was suddenly increased meant that the boiling reactor could not be regarded as load-following where sudden increases in load were concerned. The control problem could be very much simplified by the adoption of a dual-cycle system, in which a proportion of the heat was transferred to pressurized water. By suitable balancing, it should be able to secure some of the thermal efficiency advantages of the boiling reactor, with the good control characteristics of the pressurized system. In marine work, however, there was still the question of ship movement affecting void movement to be considered; while it was unlikely to cause instability, it might be responsible for unexpected temperature transients, caused by power oscillations.

A typical control system was briefly described for a gas-cooled system, consisting of a main control loop matching gas flow to steam pressure, with three minor loops for system balancing; gas outlet temperature being stabilized by the control rods; gas inlet temperature being stabilized by feedwater heat control; steam requirements being balanced by feedwater flow control. Stability during manœuvring is ensured by steam dumping.

The instrumentation necessary to achieve safe and effective control was then briefly described, after which a section was devoted to the special design problems of marine reactors. Amongst these were several points regarding the core itself, notably the necessity of flux flattening to achieve maximum burn-up. Although burnable poisons at suitable points in the core, variation of fuel lattice pitch, and poisons or diluents introduced into the moderator during the early life of the core (and gradually removed) were mentioned, it was felt that the only method sufficiently developed for immediate use was the normal one of providing additional excess absorption in the control rods, and programming the withdrawal. An interesting suggestion regarding this method was the use of instrumentation to give irradiation information in such a form that it could be radioed to the ship's base, for the optimum control rod positions to be determined by computer, and transmitted back again.

Reviewing the possible direction of future design and research work, the authors pointed out that the instrumentation and control equipment required might be comparable with that required for guided missiles in a warship. Since the economics of merchant ship operation did not permit of specialist staff on the same scale, control systems would have to be not only built to the highest standards of quality and reliability, but would require data processing equipment to limit the operating staff required. The capital cost would be considerable, but was the only practicable line of attack at the present time. Longer-term measures would include a statistical evaluation of component reliability, with a view to cutting down on stand-by instruments, and a critical examination of the number of measurements made, with a view to their reduction. Fruitful lines of development at the present time were data-processing equipment, and the replacement of relays and valves by solid-state devices, such as transistors.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

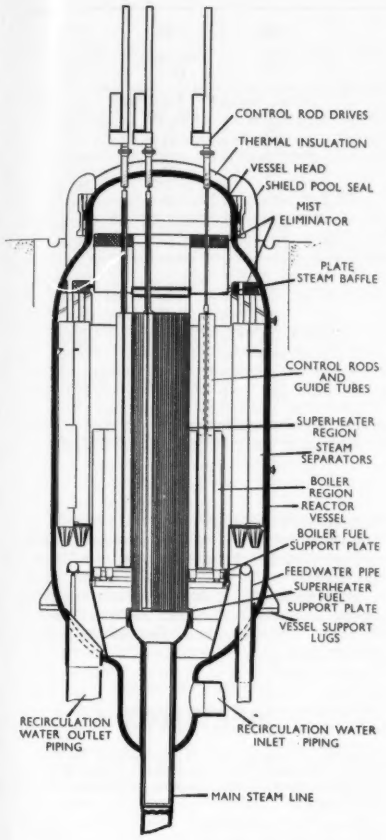
The Pathfinder Nuclear Plant. By Clifton B. Graham (Chief Engineer, Nuclear Power Department, Allis-Chalmers Manufacturing Co.).

Nuclear superheating appears to be the outstanding feature of a 66MW boiling water plant CRBR (Controlled Recirculation Boiling Reactor) to be built by Allis-Chalmers for the Northern States Power Co., at Sioux Falls, South Dakota, operation being scheduled for June, 1962.

The reactor vessel, 11 ft dia x 26 ft high, is divided into two concentric regions, boiler and superheater, the diameter of the central (superheater) core being 2 ft 6 in., and that of the boiler region, 6 ft. Water in the boiler zone is continuously recirculated by means of three pumps; this is said to enable a very high heat output from the core while still giving good flux distribution; without forced circulation the power density in the top of the core would be much reduced, owing to the high void content. Furthermore, since circulation is not dependent on density differences, as with natural circulation, high feedwater temperatures may be used, resulting in increased thermal efficiencies.

Inlets and outlets for the circulating water are both at the lower end of the reactor vessel, as is also the feedwater inlet. An interesting feature is the provision of steam

The Pathfinder Core.



separators within the reactor vessel, outside the core region; these operate on the cyclone or centrifugal separator, and, situated on the outlet side, remove entrained steam bubbles, and prevent cavitation in the pumps.

The saturated steam released from the boiling section, to the dome of the tank, passes downwards through the central superheater region. This consists of a large number of tubular elements, each consisting of tubes of uranium dioxide-stainless steel cermet clad inside and outside with stainless steel; two tubes of different diameters are assembled concentrically to form an element,

Main Parameters for CRBR (Pathfinder) plant

Gross thermal power	203 MW
Thermal power boiler region	164 MW
Thermal power superheater	39 MW
Gross electrical power	66 MW
Net electrical power	62 MW
Thermal efficiency	30.5%
Reactor	
Core height	6 ft
Core Diameter (superheater)	2 ft 6 in.
Core Diameter (boiler)	6 ft
Fuel (boiler) 1.7% enriched UO_2	117 kg
Fuel (superheater) 93% enriched UO_2-S.S.cermet	36 kg
Average heat flux (boiler)	130,000 B.t.u./ft².h
Average heat flux (superheater)	85,000 B.t.u./ft².h
Maximum heat flux (boiler)	430,000 B.t.u./ft².h
Reactor operating pressure	600 p.s.i.
Temperature (boiler)	489°F
Temperature (superheater)	825°F
Steam outlet pressure	540 p.s.i.
Recirculation rate	60,000 gal/min
Pumping power	620 kW
Gross heat rate	10,370 B.t.u./kWh

and the steam flows between and around them. The space between the tubes is filled with water moderator; double-walled tubes at the interface present a layer of stagnant steam to act as a thermal insulator between water and steam. The fuel in the superheater section is 93% enriched; that of the boiler section is 1.7% enriched. Aluminium alloy is to be used for the boiler fuel, providing corrosion resistance is adequate; research work is going on, with a limited back-up effort on Zircaloy.

Much of the remainder of the plant is of conventional design. Containment of the reactor and pumps is to be provided; the turbine and other gear is to be housed in an ordinary building, but close approach to turbine and feedwater heaters is limited to a certain number of hours per week. Main parameters of the scheme are given in the table.

An Advanced Pressurized-water Reactor Electric Generating Station. By J. B. Anderson (Combustion Engineering) and C. T. Chave (Stone and Webster).

Reference has already been made to the comparative reactor study carried out by a number of companies for the AEC (*Nuclear Engineering*, February, 1960, p.77) and this paper is based on the pressurized-water study carried out by Stone and Webster Engineering Corporation and Combustion Engineering Inc. In addition to describing the philosophy leading up to the reference design (i.e., that presented to the AEC) the paper reviews further advances which, it is considered, would be possible if further time were available for development; i.e., unhampered by the dates set for the start of construction in the AEC study. There is some very interesting material on comparative core designs studied; uniform, seed-blanket, zoned and spiked; a zoned core (i.e., higher enrichment in the peripheral layers) has been selected for the reference design, but the authors seem to favour the spiked core for future developments. Control concepts are also interesting, neutron rectifier control units being used in place of plain absorber units. Another feature of interest is the proposal to use self-pressurization in the system, in place of the conventional separate pressurizer. Possibly the most thought-provoking portion of the paper, however, is contained in the early pages:—

> . . . "In the past, there was a tendency to regard pressurized and boiling-water reactors as two different systems, each possessing unique advantages and limitations. Today, design trends of pressurized and boiling-water reactor systems are converging; advantage is being taken of the best features of each. It is expected that this trend will continue and that light-water systems may ultimately come to represent one reactor type with design variations tailored to meet the needs of each specific application."

Pressure Vessel Overtemperature Hazards. By D. B. Rossheim, J. J. Murphy, G. P. Eschenbrenner, R. S. Eagle (all of M. W. Kellogg Co.).

Emphasizing the shortcomings of existing codes in providing guidance for design against stresses due to overtemperature, the paper reviews the potential sources of over-design metal temperatures, the measures for detection of overtemperatures and the principles of minimizing hazards therefrom. An appendix summarizes the experience of eight operating companies with the use of internal insulation.

Another Step in Water Reactor Plant Technology. By A. R. Jones (Westinghouse).

This paper reports, very briefly, on the results of a series of studies to determine just how large the closed-cycle water reactor can be made. As is emphasized in the paper, the term "closed-cycle" is used, rather than the "pressurized water" hitherto more commonly used, it being stated that the conventional term implies a complete absence of boiling.

In the past, it has been expected that the upper limit for this type was around 200-250 MW(e); the Yankee design being 134, while Indian Point, although rated at 275 MW(e),

Main parameters of the Yankee (A) unit, with the proposed 330MW design (B).

	A	B
Core		
Thermal rating MW	392*	1140
Diameter ft	6.2	9.1
Length ft.	7.5	10
Uranium te	21	59
Reactor Vessel		
Height ft.	31.5	41
Diameter in.	109	142
Thickness in.	8	10
Steam Generators		
No.	4	5
Output lb/h	460,000	860,000
Total steam flow lb/h	1,840,000	4,300,000
Throttle press. p.s.i.a.	465	650

* First core

is only partly nuclear, a proportion of the power being supplied by oil-fired superheaters. The results of these studies, however, indicate that design could be carried out to some 400 MW, although the upper economic limit was set, not by nuclear considerations, but by turbine rating. Maximum economy, in fact, was secured at the point where turbine design changed from tandem to cross-compound, i.e., from single-shaft to two-shaft construction. This figure was determined as 360 MW(e) (gross) and the final design was for this figure (330 MW(e) net) or 1140 thermal MW. Some comparisons with the Yankee plant are given in the table. It is considered that such a plant could be built for $236/kW, and power could be generated at 8.4 mill/kWh with annual charges at 14%. If annual charges could be reduced to 9.75%, generation costs could be reduced to 7 mill/kWh.

OEEC

Towards a New Energy Pattern in Europe. Report of the OEEC Energy Advisory Commission under the chairmanship of Prof. Austin Robinson. H.M.S.O. 9s.

This report reassesses the prospective energy requirements and supplies of Western Europe, and considers the economic, financial and political problems linked with future development in the energy field. It takes into consideration extensive new oil and natural gas resources discovered since the Armand and Hartley Reports; also the changeover from a sellers to a buyers market in coal, and attempts to view the long-term trends against which the major decisions of the energy industries must be made.

The report is a lengthy one (125 pp.

including appendices) and available space admits of only brief mention of one or two points. The estimated demands and potential supplies of primary energy are given in the accompanying table.

On the question of nuclear energy, there is a considerable amount of uncertainty, but it is felt that it will not be fully competitive with conventional forms of energy before 1970-75. Most countries, it is stated, are deliberately buying experience in this field, which may be valuable to them in meeting their own requirements and, possibly, in developing export markets. Both constructional costs and fuel costs are expected to fall more steeply than those of conventional stations.

Even taking an optimistic view, it is considered that the contribution to total energy supplies in Western Europe will not exceed 10% by 1975, and is more likely to be 5%. The actual figures, which are widely spread, are 33-46TWh in 1965 and 60-210TWh in 1975, the corresponding installed capacities being 5-7GW in 1965, and 10-35GW in 1975 (1GW = 1,000MW, 1TWh = 1,000,000,000 kWh.).

Primary Energy in OEEC Area—Estimated Demand and Potential Supplies
(million tons of coal equivalent)

	1955	1965	1975
Estimates of Total Demand	777	970–1050	1255–1425
Mean of Estimates	777	1010	1325
Potential Indigenous Supplies:			
Coal	477	440–480	430–495
Lignite	30	45	60
Crude Oil	13	30	50
Natural Gas	7	25	50–60
Hydro-power	56	95	140
Nuclear Energy*	—	15–20	30–90
Other Fuels	20	20	20
Total	603	670–715	780–915
Mean of Estimates	603	690	850
Potential Imported Supplies:			
Oil	146†	260–310	380–500
Natural Gas	—	5‡	10–75
Coal	28†	10–60	10–60
Total	174†	275–375	400–635
Mean of Estimates	174†	325	515
Total Potential Supplies	777	945–1090	1180–1550
Mean of Estimates	777	1015	1365

* Although nuclear energy is shown under indigenous supplies, it should be noted that the greater part of the fuel will have to be imported.
† Taking account of stock changes.
‡ A notional figure.

AEA

AERE-M538. A Boiling-water Rig for Demonstration Purposes. By H. Bowes. (H.M.S.O. 7s.)

Describes the rig designed for the Harwell Reactor School to investigate heat transfer in flowing water. By its aid, either single-phase flow, or duplex phase (water/steam mixtures) may be investigated, and a thorough investigation made of the three main types of this, i.e., sub-cooled boiling, nucleate boiling and slug boiling. Practical advice is given on the design and construction of such a rig, for technical colleges, and appendices describe a number of the components, including the gamma-ray density gauge.

AERE-R-2947. The Organization at A.E.R.E., Harwell, for Safety Clearance of Reactors. By N. G. Stewart and L. Wilson. (Health Physics Division). (H.M.S.O., 2s. 6d.)

This report reviews the methods developed at Harwell for ensuring that a project is intrinsically safe, before operation. The final arbiters are the Research Group Reactor Safety Clearance Committee who, in addition to disseminating general information on safety, and maintaining liaison with the Health Physics organizations at Research Group establishments and with the Authority Health and Safety Branch, are responsible to the Director of the Research Group for considering and advising the respective establishment heads on submissions made to it regarding the nuclear safety of reactors (including sub-critical assemblies) in Research Group establishments.

The parent committee does not, however, scrutinize the safety documents directly, for various reasons, amongst which are the inability to devote sufficient time to the number of reactors requiring clearance, and the possibility that some of its members might have some executive responsibility for the reactor in question. Responsibility for detailed scrutiny therefore devolves upon working parties, one for each reactor.

The actual preparation of the safety documents, however, falls on those responsible for the design and construction of the reactor. They are, in effect, called upon to show that the project is safe. It has been pointed out that the preparation of a safety document is really a job for a specialist safety staff, but it is felt that the very advantage of this—that all relevant points are covered—would tend towards a stereotyped outlook, and a possibility that special features of each new job might not be adequately considered.

The right people, it is emphasized, are those responsible for design and operation; not only will they have the most intimate knowledge of the project, but if they have the job of proving that it is safe, it is more likely to be so, and the process of writing a safety document which will have to withstand detailed criticism often leads to improvement. For the same reason, the working party scrutinizing the documents is not composed of full-time safety staff, but consists of those actually engaged in the design or operation of reactors, on the "poacher-turned-gamekeeper" principle.

Appendices list the topics to be dealt with in a safety document, and a specimen clearance certificate.

B.W.R.A.

The Design of Welded Pipe Fittings. By P. H. R. Lane, B.Sc.(Eng.), A.I.M., and R. T. Rose, B.Sc., Ph.D. (B.W.R.A. Abington Hall, Cambridge. 15s.)

Welding permits—in fact, demands—a more rational approach to mechanical design than the time-honoured "practical" approach, using relatively inexact methods with a large factor of safety, to compensate for gaps in the designer's understanding of the stresses acting in complex components. This report gives details of extensive stress measurements on bends and elbows, extending classical methods to cover the short radius and thin-walled bends which have been increasingly used in recent years.

Stress measurements on fabricated branch connections give a rational basis for comparison of the effectiveness of various forms of reinforcement; the fatigue strength of pipe butt joints and of various designs of closures. Detail design of welds and the importance of various classes of defect are also considered, as is the practical application of the research work reported.

While the booklet does not attempt to be a pipe-design manual, it does provide the supplementary information so necessary with the present-day trend towards more compact plant.

(Dr. Rose is familiar to readers as the author of "Pressure Vessel Nozzle Design," *Nuclear Engineering*, December, 1958, p. 523.)

MEETINGS

March 2.—Institution of Mechanical Engineers, 6 p.m. Nuclear Panel Discussion, "**The Rôle of Formal Education and Training in Nuclear Power Developments.**"

March 3.—Joint meeting of the Institutions of Civil, Mechanical, and Electrical Engineers (at the Institution of Electrical Engineers 5.30 p.m.). Sixth Graham Clark Lecture, "**The Engineer and Civilization.**" Sir Hugh Beaver.

March 3.—Institute of Physics (Aberdeen, at the University, 7.30 p.m.). "**Biological Hazards of Radiation.**" Prof. J. Rotblat.

March 4.—Institute of Physics (Edinburgh, at the University, 7.15 p.m.). "**Biological Hazards of Radiation.**" Prof. J. Rotblat.

March 7.—Institute of Physics (Glasgow, at the University, 7.15 p.m.). "**Biological Hazards of Radiation.**" Prof. J. Rotblat.

March 8.—British Institution of Radio Engineers (West Midlands section, at Matthews Boulton Technical College, Birmingham, 7.15 p.m.). "**Transistor Power Amplifiers.**" F. Butler.

March 9.—The Institute of Fuel (London, at Institution of Civil Engineers, Gt. George Street, S.W.1, 5.30 p.m.). "**Nuclear Power for Ship Propulsion.**" Dr. J. E. Richards.

March 9.—Institution of Chemical Engineers (North Western Branch, at Leeds University, 7 p.m.). "**Recent Developments in Heat Transfer.**" O. A. Saunders.

March 16.—Institute of Welding (at 54 Prince's Gate, 7.30 p.m.). "**Improved Steels and Their Welding.**" J. F. Wilkinson.

March 16.—Institution of Electrical Engineers (Supply Section, at the I.E.E., 5.30 p.m.). "**An Electrostatic Dust Monitor.**" D. H. Grindell.

March 21.—The Institute of Physics (Edinburgh, at the University, 7.15 p.m.). "**Recent Developments in Scintillation Counting.**" Dr. J. B. Birks.

March 22.—The Institute of Physics (Glasgow, at the University, 7.15 p.m.). "**Recent Developments in Scintillation Counting.**" Dr. J. B. Birks.

March 22.—The Institute of Physics (London, at 47 Belgrave Square, 5.30 p.m.). Group A.G.M. followed by "**Neutron Sources.**" P. O. Hawkins.

March 25.—Non-Destructive Testing Society (at British Institute of Radiology, 32 Welbeck Street, W.1, 7 p.m.). "**Some Problems in the Fabrication of Pressure Vessels and Chemical Plant.**" B. Banks.

NEW BOOKS

Nuclear Radiation Measurement. By J. Sharpe, B.Sc., A.M.I.E.E. (The *Nuclear Engineering* Monographs Series, 71 pp., 27 illus. Temple Press Limited, 12s. 6d. net.)

The type of reader for whom this Monograph series is intended—the student, the research assistant, anyone in fact who needs a general understanding of a subject without having to dig too deeply—will find this book packs a surprising amount of information into a brief, easily digested text.

Since a solid grounding in the fundamental processes is of the first importance, the book devotes more than 20 pages to the interaction of radiation with matter; the equivalence of mass and energy, loss of energy in matter, detection and ionization media, and uncharged radiation. The difficulty of visualizing various types of neutron reaction is overcome by diagrams which are very easy to follow.

Having shown how radiation may produce ionization, secondary emission or fluorescence, the general principles of detectors are dealt with. In addition to earlier devices such as cloud chambers and other forms of track recorder, ion chambers and crystal counters are reviewed together with the principles of gas multiplication and methods of quenching leading to the Geiger counter. Several types of secondary emission detectors, photomultipliers, and scintillation counters are also described. Ancillary apparatus such as d.c. amplifiers, discriminators, scalers and ratemeters are discussed in the next chapter, together with the elements of anti-coincidence circuits and low background counting. The final chapter deals with applications of detectors for specific types of radiation. For those wishing further information, there is a bibliography of some 100 references.

Nuclear Reactor Optimization. By P. H. Margen, B.Sc.(Eng.), M.I.E.E. (The *Nuclear Engineering* Monographs Series. 81 pp. 30 illus. Temple Press Limited, 12s. 6d. net).

Optimization, or the methodical selection of the best combination of a number of variables, is by no means a simple matter even with comparatively straightforward problems. The optimization of a reactor, with upwards of ten variables, is by far from simple. It is, as the author points out, possible that four variations of ten variables could require almost a million separate designs for the complete solution of the problem—hardly a practical proposition, even with the aid of computers. By the use of more subtle methods of approach, however, it is possible for a single designer, assisted by a physicist, to carry out the optimization of the main features in a reasonably short time.

As with the other titles in this series, the approach is simple and direct. The principles of optimization are first demonstrated on something elementary—in this case, the classic Kelvin Law equating cable losses with annual charges. Next, nuclear reactors are considered, and the variables from the point of view of both physics and thermal design are, as it were, "sighted." The next chapter deals with the sequence of design and optimization calculations, the number of degrees of freedom of different parameters, and the necessity for adopting an orderly sequence. Further chapters deal with the optimization of the physics, the heat transfer and the thermodynamics.

A typical reactor design is worked out numerically, and a particularly valuable feature is the inclusion, in an appendix, of a comparison between the designer's original guess and the results of the "first round" optimization. Other appendices cover cost formulæ and tabulated data. A bibliography is included.

Naturally, in the short space available, it has not been possible to produce a reactor design manual, but the author has gone a very long way to throw light on a very difficult subject.

Radioisotopes for Industry. By Robert S. Rochlin and Warner W. Schultz (G.E. Company). (190 pp., Reinhold Publishing Corporation, N.Y., and Chapman and Hall, Ltd., 38s.)

This book sets out to inform the average practising engineer of the possibilities offered by the now comparatively plentiful supply of radioactive isotopes and instruments for measuring their behaviour. It succeeds admirably.

An opening section describes the rapid rise in the use of active isotopes in the past few years, and continues with qualitative descriptions of the limited amount of technical jargon used in the rest of the text (half-lives, αs, βs, γs). No prior knowledge of the subject is required. However, the reader is expected to have an understanding of many standard engineering processes to which the radioisotope technique is applied. This raises no difficulties for the trained engineer but might bewilder an engineering student of limited practical experience.

The major part of the text follows a well-defined pattern. Each aspect of the use of isotopes is allotted a chapter which consists of an introduction to the fundamental principles involved, followed by descriptions of a number of case histories in which the principles are exploited. Thus there are sections on "Gauging Without Contact," "Radiography and Autoradiography," "Wear Measurement," "Activation Techniques," "Using Tracers in Research and Development," "Using Radioisotopes in Manufacturing" and "Finding Leaks with Radioisotopes." The book concludes with sections on "Equipment. Facilities and Training" (unfortunately restricted to consideration of courses operating in the United States) and "Protection from Radiation Hazards." Various appendices list useful radioisotopes, give details of nuclear reactions with neutron activation tables, and list many useful reference works.

The book will serve as a complete instruction for the engineer who wants to know if radioisotopes are applicable to his particular problem. If his problem is an old one, it is likely to be described: if it is a new one, then the engineer can obtain sufficient knowledge from the book to discuss his needs intelligently with a consultant. The book is therefore recommended for the industrialist, but is probably too general for all but an introduction to the subject for the man who intends to specialize in these techniques. M.D.W.

Nuclear Reactions. Vol. 1. Edited by P. M. Endt and M. Demeur. (502 pp. North Holland Publishing Co. 86s.)

The subject matter of this work is restricted to those nuclear interactions which are energetically below the threshold for meson products. Despite this restriction, and the fact that radioactive decay processes are also excluded, two volumes will be required to cover this field adequately. This, the first, is not a text-book in the strict sense, but a collection of review articles by 11 independent authors.

Nearly half the book is devoted, quite properly, to four papers on nuclear structure and nuclear models. It is not clear why these papers have not been grouped together at the beginning of this work, since they form a suitable introduction to the main subject.

Experimental surveys include the pioneering field of heavy ion reactions, resonance reactions, neutron resonances in heavy nuclei and particle scattering at medium energies. Resonance reactions are also dealt with theoretically and an accidental mix-up of titles in the list of contents produces an amusing result. The only other theoretical paper which deals directly with nuclear reactions is an impressive account of angular correlations and polarizations.

The individual papers are of an extremely high standard, written by acknowledged experts, and the work as a whole is undoubtedly valuable. The editors take the trouble to apologize for some overlap between contributions. Such overlap is not a serious fault. It is a pity, however, that in books of this type, which are becoming increasingly common, some system cannot be devised to provide cross references between the individual contributions.

The second volume is awaited with interest and there is good hope that, when it arrives, the editors will have succeeded in comprehensively covering this difficult field. The material will prove of great interest to nuclear physicists, though its connection with nuclear engineering is somewhat tenuous. A.A.J.

Books Received

Nuclear Fuel Elements. Edited by Henry H. Hausner and James F. Schumar. Pp. 409. Reinhold Publishing Corp., 430 Park Avenue, New York, 22. N.Y. $12.50.

Progress in Nuclear Energy. Vol. I Plasma Physics and Thermonuclear Research; Vol. II Economics. (Edited proceedings of the 1958 Geneva Conference.) Pergamon Press, Ltd., 4 and 5 Fitzroy Square, London, W.1. £5 5s. each.

Detecteurs de Particules. By Daniel Blanc. Pp. 323. Masson et Cie, Paris. 3,900 fr.

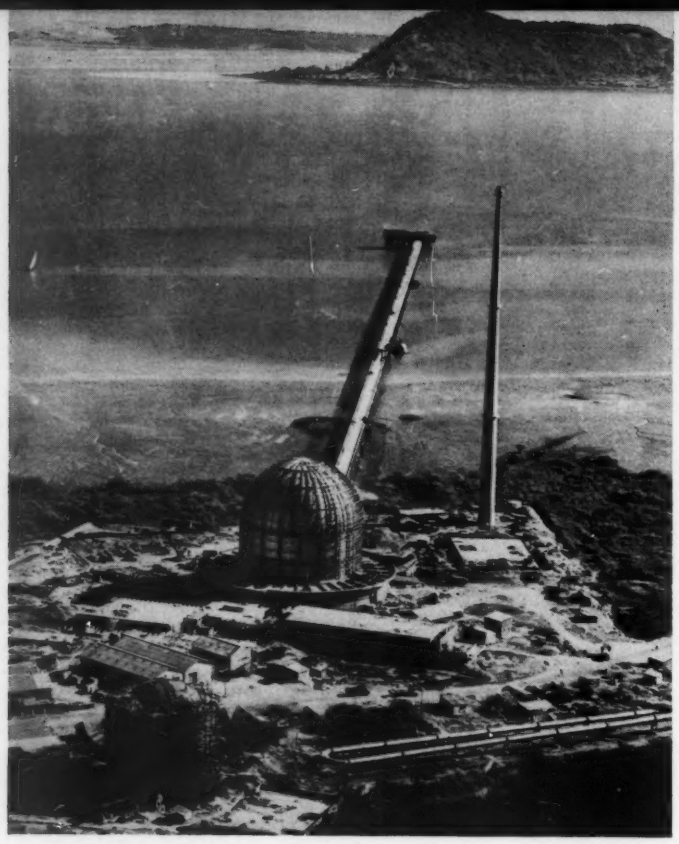
Glossaria Interpretum. (Dictionary of Nuclear Physics and Atomic Energy in English, German, French and Russian.) Pp. 213. Elsevier Publishing Co. (D. Van Nostrand Co., Ltd., 358 Kensington High Street, London, W.14.) 30s.

High Pressure Chemical Plant. (Second Edition.) By Harold Tongue. Pp. 250. Chapman and Hall, 37 Essex Street, London, W.C.2. 4 gns.

Electron Physics. By O. Klemperer. Pp. 248. Butterworth Scientific Publications, 4 and 5 Bell Yard, London, W.C.2. 32s. 6d.

The Industrial Challenge of Nuclear Energy. (III). (1959 Stresa Conference Part I.) Pp. 275. O.E.E.C. Publications. 18s. 6d.

World News



The Indian Atomic Energy Commission's research centre at Trombay near Bombay, showing the 40 MW NRX-type reactor, CRI, being built by Canadian and Indian engineers under the Colombo Plan. In the lower left corner is the zero-energy, heavy-water type reactor, ZERLINA, also still under construction. The chimney tower on the right is 450 ft high.

International

ALTHOUGH NO RATIFICATION has been received from the Italian Government to turn the research centre at Ispra into a Euratom establishment, research terms and initial programmes, including equipment required, have been prepared by Euratom.

A MACHINE for the automatic recording and classification of scientific information is being sought by Euratom. It is planned to connect such a machine by Belinogramme and Telex with the major European nuclear research centres.

AN EMBASSY, representing Euratom, the Common Market and the European Coal and Steel High Authority is to be established in London.

THE MEASUREMENT and analysis of samples of air, water, soil, and food will be undertaken by the IAEA to help determine the degree of radioactivity on earth. The survey will help in setting rules and standards with regard to waste disposal.

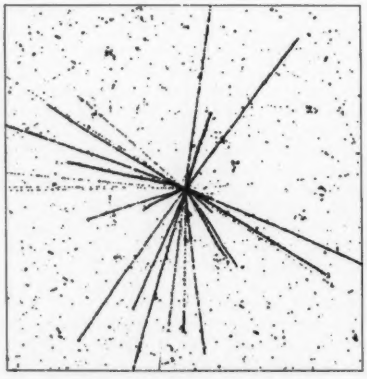
AN INTERNATIONAL training course on radioisotope techniques for agriculture was held in New Delhi during the First World Agriculture Fair. The course was organized by the IAEA and UNESCO in conjunction with the Ministry of Food and Agriculture of India.

A WORKING GROUP, representing seven member states of the IAEA is to be established in connection with nuclear safeguards and health protection. The member states are: Brazil, Czechoslovakia, France, India, U.S.S.R., U.K. and U.S.A.

MEETINGS HAVE TAKEN PLACE at the IAEA headquarters in Vienna for the advancement of international regulations for the safe transport of radioactive materials.

A REVIEW of the world position with regard to the exploitation and evaluation of uranium and thorium deposits, has been published by the IAEA. Entitled, *Surveying and Evaluating Radioactive Deposits*, the review was prepared by Mr. A. H. Lang of Canada.

TWO COURSES on nuclear energy for engineers and technicians are being organized by the OEEC this year. The first will be held at Saclay June 27-July 8 and the second at Harwell July 4-15.



One of the first microphotographs of the disintegration of a nucleus produced in a special photographic emulsion by an artificially produced high energy particle in the 25 GeV proton synchrotron at the CERN laboratory near Geneva.

United Kingdom

CONSENT HAS BEEN GIVEN by the Ministry of Power to the CEGB for the construction of a 650 MW power station at Sizewell in Suffolk. This will be the seventh civil nuclear power station in the U.K. and will be the largest. It is expected to cost between £60 and £65 million and tenders for construction are being sought now. The station will occupy a site 200 acres in size and will provide an addition of £150,000 to the rateable value of the area.

INVITATIONS FOR TENDERS to provide the reactor and propulsion for a nuclear-powered surface ship have been issued by the Ministry of Transport to the following: A.E.I.-John Thompson, Babcock and Wilcox, English Electric, Hawker Siddeley Nuclear Power and Mitchell Engineering.

FOUR SCIENTISTS, in the Nuclear Physics division at Harwell, have completed experiments which help to confirm a basic conception of Einstein's General Theory of Relativity. The experiment entailed the passing of gamma rays from the isotope of iron Fe^{57} down an evacuated tube for a distance of 40 ft. The rays were absorbed in iron of the same nuclear structure as the source and carefully recorded. An alteration in the wavelength of the rays was found to occur as predicted by Einstein. The scientists were: Dr. T. E. Cranshaw (U.K.), Dr. J. P. Schiffer (U.S.A.), Dr. A. B. Whitehead (Can.) and Dr. H. J. Hay (N.Z.).

A COMMITTEE has been set up by the South of Scotland Electricity Board to establish administrative bodies for the protection of the inhabitants in the Hunterston area.

Argentina

AUTHORIZATION has been given by the Board of Governors of the IAEA for a mission to be sent to the Argentine to survey the nuclear power needs.

Australia

A **SINGLE GROUP** of laws has been called for by the AEC to control the use of radioactive materials in Australia. The lack of suitable laws in any one State could impair control of others and clear authority is requested on a long-term basis.

HIFAR is now operating at full power. The reactor is a 10-MW DIDO type.

Austria

AN INQUIRY has been sent to the IAEA from the Government as to whether it would be possible for the Agency to supply uranium fuel enriched to 90% for the 5-MW reactor now under construction at Seibersdorf. The fuel is required for continued operation of the reactor, the first fuel loading being supplied by an American concern.

A FIRM, Austro-Chematom Kernbrennstoff, has been formed for the manufacture of nuclear fuel elements at Linz. Three concerns, Rio Tinto, U.K.; Deutsche Gold and Silver Scheideanstalt (Degussa), West Germany and Osterreichische Stickstoffwerke Aktiengesellschaft, of Linz, are responsible for the setting up of the concern.

Finland

ENRICHED FUEL for the first reactor, a TRIGA Mk. II type, is to be obtained through the IAEA. The Agency will negotiate for the supply of 20% enriched uranium from the U.S. for the reactor and for 10% enriched uranium from the U.S.S.R. to fuel a critical assembly. It is planned to build the critical assembly in Finland but the TRIGA will be supplied by General Dynamics, U.S.

France

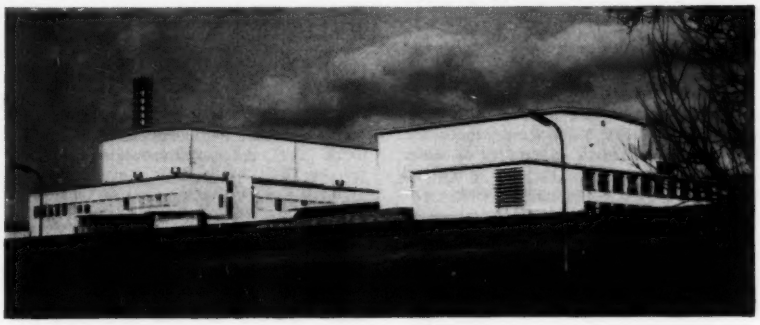
A DONATION of electronic equipment worth $30,000 has been made to the IAEA. The equipment will be used for radioactive measurement.

Greenland

AN AMERICAN PLAN to build a 1.5-MW power-producing reactor has been approved by the Danish Government. The reactor will supply power for a new scientific base, Camp Century, now being built 100 miles inland, east of the coastal base at Thule. The reactor will be built in the U.S.A. in sections and then assembled on site.

West Germany

FULL POWER has been reached by the 50-kW solution-type research reactor built by Atomics International at the Institute for Nuclear Research.



The Boris Kidric nuclear research centre at the Institute for Nuclear Sciences at Vinca, near Belgrade.

Canada

THE SECOND nuclear research centre to be constructed in Canada will be built 60 miles east-north-east of Winnipeg. It will be known as the Whiteshell Nuclear Research Establishment and work is expected to begin in 1951. Shawinigan Engineering have been contracted to do site planning and engineering with the assistance of engineering firms in Winnipeg. It is possible that the centre will house an organic-cooled, heavy water moderated power reactor.

Denmark

THE 10-MW DMTR REACTOR at the Risø research centre went critical on January 17. Built by Head Wrightson, the heavy water moderated, enriched fuelled reactor is of the PLUTO type.

A MAJOR scientific conference, organized by the IAEA, is to be held in Copenhagen from September 6-17. The conference will deal with the use of radioisotopes in the physical sciences and industry.

India

IT HAS BEEN REPORTED that British firms are to be asked to tender for a nuclear power station in India. No details are available yet, however.

THE FIRST RESEARCH GRANT under the IAEA exchange and training programme has been awarded to Dr. R. P. Agarwala of India. He will undertake 12 months' research in solid state physics and chemistry at the Massachusetts Institute of Technology.

THE DESIGN of a high level radiation laboratory has been awarded to Vitro International, New York. The laboratory is expected to cost $4 million and will be constructed at the research centre at Trombay. It will incorporate a number of hot cells for radiation experiments with plutonium.

DIRECTOR-GENERAL of the IAEA, Mr. Sterling Cole visited India during February. Besides visiting the nuclear research centre at Trombay, Mr. Cole saw a number of other scientific institutes.

Italy

THREE FIRMS, Agip Nucleare, Fiat and Montecatine (Sorin) are to participate jointly in a CNRN financed project to be known as PRO. The plan calls for the establishing of an organic moderated prototype reactor of 30 MW.

A MISSION from Euratom has been in Rome since January 11 for discussions with the Italian Foreign Affairs Ministry about some of the clauses of the treaty to lease the nuclear centre at Ispra to Euratom as the Commission's main research centre. Ratification is needed by the Government before permission can be given.

AN AGREEMENT between Cantieri Riuniti dell'Adriatico, one of the country's biggest ship builders, and Babcock and Wilcox (U.S.) has been signed for the construction of nuclear-powered merchant ships. The agreement is valid for 10 years.

THE DRAFT of a basic law in nuclear matters has been sent by the Government to the Senate.

RATIFICATION has been given by the Foreign Office to the OEEC for the Eurochemic project. Italy has subscribed to 44 of the 430 Eurochemic shares.

A RESEARCH and development programme, under the U.S.-Euratom agreement, will be undertaken between the Italian firms, CISE and Ansaldo, and Nuclear Development of the U.S. The programme, totalling about $550,000, involves an engineering design and experimental investigation of a new method of cooling power reactors. The method begins with a mixture of high pressure steam and water droplets and is known as fog-cooling. The mixture passes through the reactor picking up heat and causing the droplets to evaporate into steam, and the steam is then fed directly to the turbo-generators.

Netherlands

THE TWO COOLING SYSTEMS and part of the reactor installation on the high flux, 20-MW reactor at Petten, are finished and the chemical system is expected to be completed in several months' time.

Puerto Rico

A JOINT CONTRACT has been signed by the Puerto Rico Water Resources Authority with the U.S. AEC for participation in a demonstration power plant in Puerto Rico. The proposal is to build a 16.3-MW boiling-water type producing superheated steam within the core and using uranium dioxide fuel. The plant is expected to cost $11 million and under the terms of the contract the Authority will provide the site and conventional turbo-generating facilities and operate and maintain the plant on a reimbursable basis.

South Africa

FOUR SCIENTISTS, from the Atomic Energy Board, are to spend a year at the Argonne National Laboratories, U.S., for study purposes. They are: Dr. W. L. Grant, chief engineer; Dr. S. J. du Toit, assistant chief physicist; Dr. P. J. Hugo, assistant chief metallurgist and Dr. L. J. le Roux, chief chemist.

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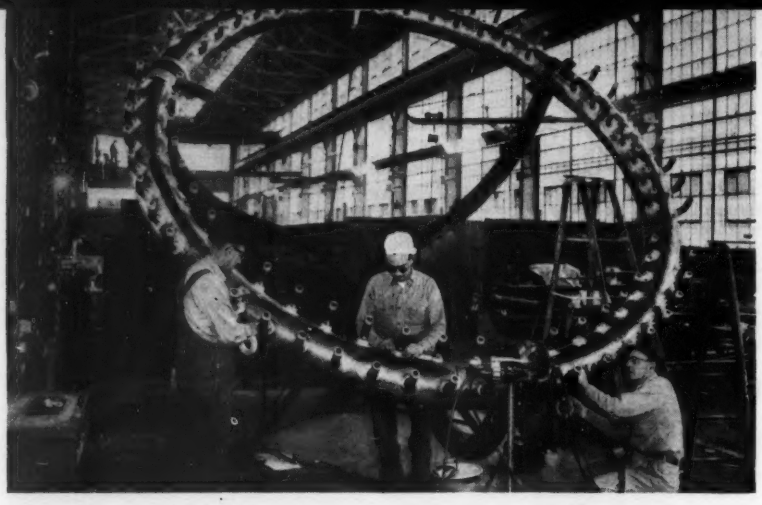


An outlet header for the Hanford plutonium recycle test reactor under construction by General Electric for the U.S. AEC. The header is made of stainless steel 10⅜ in. outside diameter with a 0.75 in. wall thickness and consists of three welded segments making the diameter of the ring 13 ft 6 in.

Spain

PROGRAMMES have been issued by the Spanish National Committee for the sectional meeting of the World Power Conference which is to be held in Madrid from June 5-9. Copies can be obtained from the British National Committee, 201 Grand Building, Trafalgar Square, London, W.C.2.

AN AGREEMENT for co-operation in the peaceful uses of nuclear energy has been signed with the U.K. The agreement is on similar lines to those signed between the U.K. and Italy and Japan. It is designed to provide the frame-work within which co-operation can take place between institutions and private firms. Provision is also being made for the training of Spanish scientists in the U.K.

Sweden

PROPOSALS for a cross-flow heavy-water type of reactor have been put forward by AB Atomenergi and the Swedish Power Board. No technical details are available yet but it is believed that the fuel elements would be arranged in horizontal layers. The heavy water coolant and moderator would then flow across the fuel elements in a vertical direction.

Yugoslavia

CERTAIN MODIFICATIONS will have to be made to the zero power reactor at Vinca before the experiment can be carried out which will duplicate conditions under which the team of research workers were injured in 1958. Using heavy water moderator the reactor will be operated at a level of 5W for a period of four hours and at 500 W for one hour during the dosimetry experiments.

U.S.A.

EXPORTS of nuclear energy products, manufactured in privately owned establishments in the U.S., were valued at $148.9 million in 1958 according to a statement recently issued by the Department of Commerce. Completed reactor fuel elements delivered directly for installation were valued at $23.9 million.

A POLICY has been formulated by the AEC for land disposal of radioactive waste, and Government controlled sites are to be established with long-term control. In a statement concerning waste disposal, Mr. J. A. Lieberman of the AEC has said that the Commission are now spending $6 million annually and has $200 million invested in disposal facilities.

IT IS REPORTED that plans and specifications have been made available for bids for work on Spert IV, the pool-type experimental facility for basic reactor kinetic studies at Idaho Falls.

ONE YEAR'S CONTINUOUS OPERATION is reported on the small size nuclear generator, SNAP 3. Heat produced by the radioactive decay of polonium-210 is converted directly into electrical energy in this system by a series of thermocouples.

A SHARP INCREASE in the shipments of radioisotopes from the Oak Ridge National Laboratory is reported for 1959. Nearly 300,000 curies, representing an increase of 31% more than 1958, were shipped last year.

THE SECOND CORE has been installed in the KEWB facility at the Atomics International Burro Flat Field Test Laboratory. The facility is a kinetic experiment on water boilers developed to evaluate abnormal operating conditions in these systems.

THE SODIUM-GRAPHITE reactor critical assembly began operating at the Atomics International field laboratory in the Santa Susana Mountains, Calif., on January 26. The assembly is part of a research programme being undertaken for the AEC. Nineteen fuel elements were used for the start-up of the 8 ft by 12 ft diameter assembly. The elements are comprised of stacks of 1 ft by 1½ in. uranium cylinders encased in aluminium.

A LICENCE has been issued permitting the boiling water power station, Dresden, to be operated at 50% of its rated power. The 180 MW station went critical on October 13, 1959. The original troubles with control rods have now been largely resolved.

THE DESIGN and supply contract for a new heavy water type research reactor has been awarded by the AEC to AMF. Construction of the 5-MW facility is expected to start in 1962.

A SECOND HOLE measuring 1½ in. x ½ in. has been revealed on inspection of the core tank of HRE-2, located just below the equator. The reactor has been operating as a one-zone system. After repair, flow through the reactor is to be reversed and other modifications made to eliminate local stagnant spots.

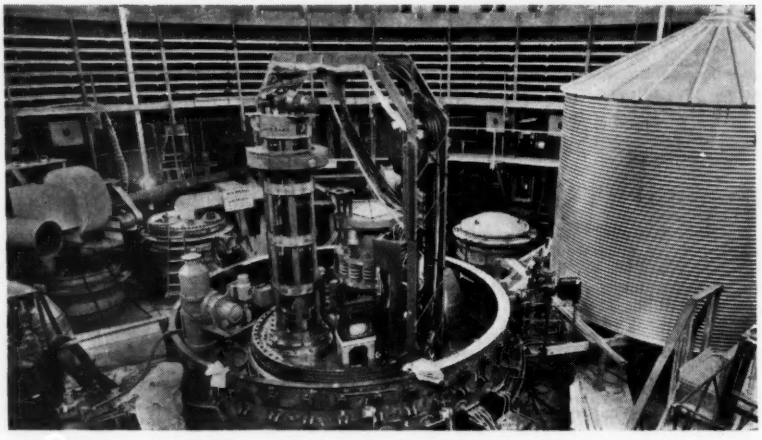
HELIUM-3 has been reduced in price by 90%. The cost per cubic foot is now 15 c and the special packaging charge for amounts over 1,500 cc has been reduced from $75 to $50 according to an announcement by the Oak Ridge National Laboratory.

URANIUM FUEL for the Indian Point, 275 MW power station being built for Consolidated Edison by Babcock and Wilcox will be supplied by Mallinckrodt. 1,000 kg of 93% uranium oxide is to be supplied. The UO_2 will be homogeneously mixed with thorium oxide and made into fuel element pellets for the reactor which is a pressurized water type.

A FIXED PRICE SUBCONTRACT of $1,174,500 for the containment shell and air locks for the experimental gas-cooled reactor (EGCR) at Oak Ridge has been awarded to Pittsburgh Des Moines Steel. The contract calls for the complete design and installation of the apparatus.

A NEW NUCLEAR fuel gauge, incorporating transistorized devices, has been developed by Atomics International. The gauge measures the fuel in aircraft and missiles.

The interior of the containment building showing the reactor, sodium pumps and heat exchangers of the Enrico Fermi Atomic Power Plant, the 94 MW fast breeder under construction at Lagoona Beach, Mich.



Personal

Mr. J. B. Laurie.

Mr. H. Cartwright.

Sir Kenneth Hague.

Air Vice-Marshal W. A. Opie.

Appointments

Mr. H. Cartwright as director of Industrial Power of the AEA development and engineering group at Risley.

Mr. J. B. Laurie as general manager (commercial) at the Production Group headquarters, Risley, of the AEA.

Sir Kenneth Hague as chairman; **Sir Reginald Verdon Smith** as deputy chairman; **Mr. A. S. Peacock** as purchasing controller; and **Mr. J. S. Greenhalgh** as manager, construction equipment division, of Babcock and Wilcox.

Sir John Wrightson as chairman and managing director of Head Wrightson.

Mr. T. R. Middleton to the board of English Steel.

Mr. G. Blain as fuel supplies officer of the CEGB.

Air Vice-Marshal W. A. Opie to the board of Irwin Technical.

Mr. L. C. Southcroft as managing director of the Superheater Company.

Mr. W. R. Boffey, Mr. B. V. Haggett and **Mr. A. J. Cartwright** to the board of United Steel and Manufacturing.

Mr. J. B. Scott as overseas sales director of Crompton Parkinson.

Mr. T. H. Shaw to the board of Thos. Firth and John Brown.

Mr. S. H. Ireland as assistant managing director of Consolidated Pneumatic Tool.

Mr. F. W. Tomlinson, Mr. J. M. Willey and **Mr. P. S. Bryant** to the board of Murex. Mr. Tomlinson has also been appointed to the board of Murex Welding Processes.

Lieut. Cdr. J. A. L. Stokes as group sales manager of Elga Products.

Mr. H. W. A. Waring re-elected as chairman of the Steel Committee of the Economic Commission for Europe.

Mr. R. R. Mason to the board of British Engine Boiler and Electrical. **Mr. K. W. Bradshaw** as general manager.

Brig. H. P. Crossland as chairman of the Zinc Development Association.

Mr. K. W. Sims as export manager of C. C. Wakefield.

Mr. L. J. Cheney as chief information officer to the Office of the Minister for Science.

Mr. O. D. Gwilliam as assistant general manager of Foster, Yates and Thom.

Mr. G. Marchant as general manager of the Wolverhampton and Hednesford factories of Fafnir Bearing.

Mr. A. W. Evans as manager of Ambuco.

Mr. A. J. Marles as technical manager of Ransome and Marles.

Mr. A. V. Edwards as managing director of the Ultra Group Holding Company.

Mr. W. E. A. Williams as sales manager of Sifbronze welding products of Suffolk Iron Foundry.

Mr. P. J. Gilbert as sales manager and **Mr. B. W. Green** as secretary of Borax and Chemicals.

Mr. C. R. Evans as manager, chemical instruments division of Servomex.

Mr. R. E. F. Sykes as general manager of Griffin and George (Laboratory Construction).

Mr. T. E. Hardy to the board of Steel Fabricators (Cardiff).

Lt.-Col. P. H. Bentley as chairman of Weyburn Engineering, **Mr. J. T. W. Scruby** and **Mr. R. H. Coverley** as joint managing directors.

Mr. V. G. Sherren to the board of George Newnes.

Mr. E. G. Wakeling to the board of Advance Components.

Mr. R. N. Millar as managing director of the Engineering Group of G.E.C.

Mr. J. C. Wells as chief engineer of the newly formed hydraulic servo division of Baldwin Industrial Controls.

The board of directors of the newly formed James Booth Aluminium is: Chairman, **Mr. W. E. Ogden**; members, **Mr. W. W. Dolton, Mr. W. J. Vaughton, Mr. A. F. Thomas, Mr. D. H. H. Clarke, Mr. D. A. Rhoades, Mr. T. J. Ready, Mr. A. H. Branstad.**

Overseas

Mr. L. C. Richards as chief engineer to Heavy Electricals, India.

Mr. T. G. LeClair as manager of nuclear power applications of General Dynamics, General Atomic Division, San Diego, Cal.

Dr. Silverman as chairman of the AEC's advisory committee on reactor safeguards.

Dr. P. N. Powers as head of the newly formed department of nuclear engineering at Purdue University. Dr. Powers has resigned as president of the Internuclear Company of Clayton but continues as a director.

Dr. S. Lawroski as co-ordinator of engineering research and development programmes at the Lemont III atomic energy facility of the Argonne National Laboratory.

Mr. F. R. Bruce as director of radiation safety and control at Oak Ridge.

Awards

Sir George Thomson the 38th award of the Faraday Medal.

Retirements

Mr. E. A. Robinson as joint managing director of the Superheater Company.

Mr. R. Miles as chairman and managing director of Head Wrightson.

Mr. E. W. Hague from the board of Thos Firth and John Brown.

Dr. H. H. Barton from the board of English Steel.

Obituary

Nuclear Engineering regret to announce the deaths of the following:—

Dr. V. Ritter, chief engineer of the Dragon project at Winfrith on January 23.

Prof. H. W. B. Skinner, head of the department of Physics, Liverpool University on January 21 at the CERN headquarters, Geneva.

Mr. A. C. Hartley, president of the Institution of Civil Engineers on January 28.

Mr. G. V. Massey of Dounreay on February 7 at the age of 31.

Dr. I. V. Kurchatov of the nuclear physics laboratory, Leningrad Physical Technical Institute, on February 9 at the age of 58.

Mr. C. R. Evans.

Mr. T. G. LeClair.

Mr. J. C. Wells.

Mr. R. N. Millar.

Industrial Notes

E. G. Irwin and Partners have been awarded a £1,000,000 contract by the AEA for the design and construction of an irradiated fuel element cave laboratory. The laboratory will be installed in the blower house of No. 2 reactor at Windscale and is to be designed to handle several thousand fuel elements a year. The facility is scheduled to begin operating by the end of the year.

Hayward Tyler have been contracted by Atomic Power Construction to supply the heat exchanger glandless circulating pumps for the Trawsfynnyd power station. Valued at £100,000 the contract calls for 24 each low and high pressure glandless pump and motor units at 350 p.s.i.

General Electric plan to use an old blanket and hosiery mill at Dalry, Ayrshire, for the storage of graphite and other core components for the two reactors at Hunterston. This has been necessary because of the time factor involved in building the core, three to four months. Each reactor will contain more than 2,000 tons of machined graphite blocks and tiles.

AEI will supply a 200MW turbine generator for Candu, the Canadian nuclear power plant to be constructed at a site on Lake Huron. The contract for the 1,000-ton unit is worth $4 million.

Short Brothers and Harland are to supply an analogue computer capable of simulating the operation of a nuclear power plant to the AEA for use at the Calder Hall Operations School for training reactor operators.

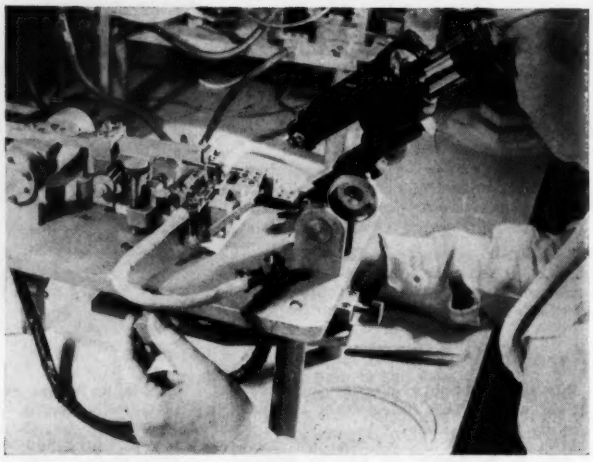
Baldwin Industrial Controls have formed a hydraulic servo division at their headquarters in Dartford, Kent. The division will offer a service for the application of hydraulic servo techniques to problems of production and experimental engineering.

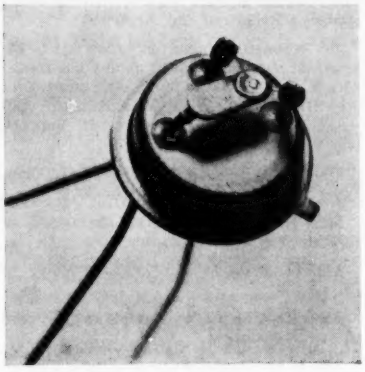
British Oxygen Gases have secured the marketing rights for the **Union Carbide** tungsten arc cutting process. The process depends on a non-consumable electrode working in a gas stream with a high cutting rate.

The British Industrial Measuring and Control Apparatus Manufacturers' Association have announced that the industry's turnover for 1959 was £35 million.

Richardsons Westgarth have formed a subsidiary in the U.S., **Richardsons Westgarth Inc.** The company will act as a selling agent in the U.S.

First of the U.K.'s nuclear concerns to announce their intention of exhibiting at the British Exhibition in New York. June 10-26, is **Tube Investments** who have taken over 3,000 sq. ft in the engineering section.





(Above) Thermocompression bonding operation in the Ferranti transistor factory with the aid of a microscope. (Right) An assembled transistor prior to encapsulation.

Ferranti have put into operation a new factory at Gem Mill, near Manchester, for the production of high-frequency, double-diffused, mesa, silicon transistors. It is estimated that by mid-1960 production will be at a rate of 25,000 units a year. Automatic equipment has been incorporated in the manufacture of the silicon diodes for the transistors and nearly 80% of the operations for the ZS 30 mesa range is automatic. Ferranti report that they have spent £500,000 in the past five years on research into transistor manufacture.

Keith Blackman now have a permanent exhibition building in Tottenham, London, N.17, for the display of their fan and industrial gas equipment.

The Imperial College of Science and Technology will hold a summer school on health physics in radiation protection starting June 4.

SIMA are to hold a British scientific instruments exhibition in Moscow during November.

B and K Laboratories announce that they will not be organizing an International Instrument Show this year.

A course of six lectures on secondary surfaces for heat exchangers will be held at **Northampton College of Advanced Technology** commencing March 2.

The **International Medical Electronics Exhibition** will be held at Olympia from July 21-27 in conjunction with the **Third International Conference on Medical Electronics.**

Delta Metal have formed a new company, **James Booth Aluminium,** for the purposes of undertaking the whole of the aluminium and light alloy interests of **James Booth and Company. Kaiser Aluminum and Chemical, U.S.,** will hold half of the issued share capital of £10 million.

New Metals and Chemicals have been appointed sole U.K. distributors for superpure silicon produced by **Trancoa Chemical, U.S.**

The **Board of Trade** has announced that some relaxation is to be made in connection with the remission of duty on instruments and apparatus under Section 6 of the Import Duties Act, 1958. The Board are now prepared to consider applications for remission of duty where the amount is £20 or more instead of £50.

An automatic transfer line for transistor manufacture has recently been commissioned at the Cheney Manor plant of **Semiconductors.** The line will enable the more complicated devices such as micro alloy diffused transistors to be manufactured automatically.

Recent changes of address are:

Metalock have opened a new office at Windsor Chambers, Bearwood Road, Smethwick, Birmingham. Tel: Bearwood 2799.

Lightfoot Refrigeration have opened a new office at Canute Road, Southampton.

The X-ray and medical sales division of **General Radiological** is now at County Building, Honeypot Lane, Stanmore, Middx. Tel: Wordsworth 4300.

Beldam Asbestos and **Auto-Klean Strainers** are now at 109 Fenchurch Street, London, E.C.3. Tel: Royal 1148.

The sales, administration and accounts departments of **Solus-Schall** are now at County Building, Honeypot Lane, Stanmore, Middx. Tel: Wordsworth 4300.

GEC's new telephone number is Erith 33011.

Processes and Equipment

For further information on any item please enter the relevant number on the Reader Service Card enclosed with this issue and forward the card to the address given.

Polythene Neutron Shielding

The mechanical and chemical properties of polythene are widely known and, in the nuclear field, its properties as a moderator and neutron shield are becoming more generally familiar. Owing to its high hydrogen content it is superior to other thermoplastics, and its low specific gravity (0.92 g/cm³) also proves advantageous. Although more expensive than water, it does not suffer from radiolytic decomposition, or evaporation, nor does it require leak-proof containers, thus considerably simplifying the engineering design. It is, however, only comparatively recently that the extrusion moulding process has made it possible to produce polythene in really large blocks, although sheets up to 1 in. thick and rods up to 6 in. diameter have been available for some time.

On the right we illustrate one of the stages in the manufacture of a cylindrical shield for a small reactor. The original "blanks" as they might be termed, may be either solid or annular, and may weigh up to 3½ cwt. as moulded. Continuity of the shield (i.e., protection against neutron streaming) is ensured by machined shoulders so that each block fits into the next, without any gap. Testing for voids presents some problems; above 6-8 in., X-ray examination is very difficult; better results have been achieved with ultrasonics, but even this is not infallible, and voids with a maximum dimension of ¼ in., are not always observable. Voids of this size, however, do not have a serious effect upon the shielding properties of the finished assembly of blocks.

Rediweld solid and annular polythene blocks, as moulded.

Boron in the form of oxide or carbide can be incorporated with a concentration of up to 4% and heavy metals can also be added to increase the gamma-ray absorption. As this operation is performed prior to moulding a homogeneous moderating absorbing shield results.

(Rediweld, Ltd., Broomhill Road, London, S.W.18.)

1271

High-vacuum Valves

A new design of vacuum valve, manufactured by Vacuum Research Co., of San Francisco, is now being marketed in Britain by Vacuum Research (Cambridge), Ltd. Available in 1-, 2-, 4- and 6-in. sizes, the valve is of compact design (the largest is only 4 in. wide) and, while giving unobstructed opening, is claimed to be suitable for vacuums of 10^{-6} mm Hg, and to be leak-tight with atmospheric pressure on either side of the valve. Operation is by 180° rotation of a lever, but air operation can be arranged if desired.

Vacuum Research high-vacuum valve.

(Vacuum Research (Cambridge), Ltd., Quayside, Bridge Street, Cambridge.)

1272

Aluminized Asbestos Cloth

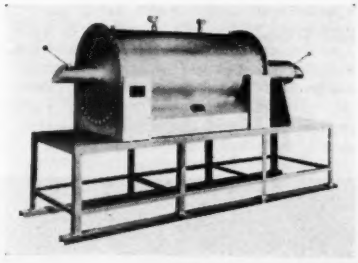
Asbestos cloth, long used as thermal or fire-resistant insulation, or as a fireproof finishing wrap over thermal insulation, is now available with an aluminium finish. Firefly aluminized asbestos cloth, has a metallic layer machine-bonded to it with a thermo-setting resin, and the finished cloth can either be applied with adhesive, or eyeletted and sewn into mattress form. The aluminium layer not only eliminates painting, but is waterproof, oilproof, and acts as a vapour barrier in cold applications. Its main feature is, however, the exceptionally high reflection of heat which is achieved, and, in addition to cutting down radiation losses, it is particularly suitable for protective clothing in hot situations. Made in several grades of coarse and fine weave, it is available in 45-yard rolls 40-42 in. wide, or as 2-, 4- or 6-in. strip.

(Turner Brothers Asbestos Co., Ltd., P.O. Box 40, Rochdale, Lancs.)

1273

Heavy-duty Sintering Furnace

A new Royce heavy-duty sintering furnace, for operation up to 1,650°C with a hydrogen atmosphere has the advantage of independence between the work tube and the heating element, so that damage to one does not necessarily involve the other, as in the case of a heating element wound directly on to the work tube. The work tube, of fused alumina, 5 in. diameter by 32 in. heated length, is surrounded by segmental tiles of pure alumina, housing the heating element, of heavy section molybdenum. Porous alumina high-temperature insulation outside this is itself surrounded by graded thermal insulation, and contained within a gas-tight cylindrical steel casing, with removable end covers.



Royce sintering furnace.

At the charging end, an extended solid-drawn tube acts as a preheat/purging

chamber; the exit chamber is water-cooled to ensure that a charge is below oxidation temperature before leaving. The furnace atmosphere—hydrogen or cracked ammonia—is preheated before entering the work tube, by percolation through the insulation; auxiliary inlets allow an increase in gas flow when charging or discharging, and a burn-off at both doors ensures the combustion of excess hydrogen.

Heating is divided into two independent zones, along the furnace length, and independent, stepless automatic control is provided. The total loading of the furnace is 25 kW (3-phase) and the charge, in carbon boats 12 in. long, has a gross weight of 14 lb. The boats are progressed through the preheat, heating and cooling chambers by a hand pusher, or an automatic pusher working to a time cycle is used where absolute consistency of results is necessary.

(Royce Electric Furnaces, Ltd., Sir Richards Bridge, Walton-on-Thames, Surrey.)

1274

Hydraulic Relief Valve

A flat characteristic over a wide flow range is the outstanding feature of a

Plessey hydraulic relief valve.

new Plessey relief valve with a temperature range up to 100°C, and a pressure range of 100-3,000 p.s.i. It will accept flow up to 10 gal/min.

(Industrial Hydraulics Division, The Plessey Co., Ltd., Ilford, Essex.)

1275

Investment Casting Service

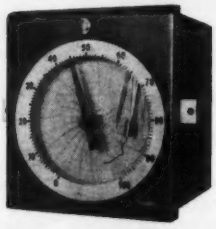
Investment casting has for some time been recognized as an economical method of producing small quantities of complex castings with a high finish. While widely used for production of castings in refractory metals, it is also eminently suitable for non-ferrous work in short runs, or where changes in design are likely. Smiths Autop Foundry are now offering an investment casting service in a wide variety of non-ferrous metals, to a maximum size of a 6-in. cube, and a maximum weight of 1 lb in light alloy, or 2½ lb in heavy alloy. The illustration shows some of the work produced.

(Smiths Motor Accessory Division, Autop Foundry, Otterspool Way, Watford By-Pass, Herts.)

1276

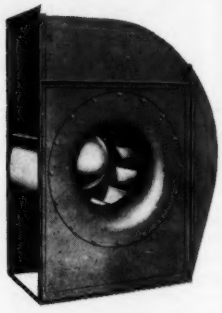
Transistorized Recorder

A new indicator-recorder, the Fielden Capacipoise Servograph, has a 300° (15 in. scale) central pointer and a 6¼ in. recording chart, with panel dimensions 8¾ in. high × 7$\frac{9}{16}$ in. wide. It is servo-operated, with a



Left: The Fielden Capacipoise Servograph transistorized recorder.

Right: New Matthews and Yates centrifugal fan.



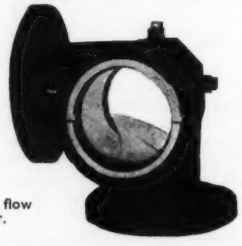
very simple mechanism, moving parts and gearing having been reduced to the minimum. Available in two main types, for 12V battery operation or from normal 240V supply with a built-in power pack, the unit can also act as a controller, high and low contacts being provided on either side of the recorder pen. Full-scale deflection can be obtained with as little as 30mV or 25 μA.

(Fielden Electronics Ltd., Wythenshawe, Manchester.)

1277

Sight Flow Indicator

The range of flow indicators manufactured by Liquid Systems Ltd., has been



New sight flow indicator.

extended to cover flanged models as well as screwed types. A 3 in. nominal bore angled type is illustrated, but the range includes instruments up to 6 in. bore. Two plugged inlets are provided for thermometer, vent, or vacuum line connection, and the indicators are available in acid-resisting bronze, cast iron, steel, or stainless steel.

(Liquid Systems Ltd., Holmethorpe Avenue, Redhill, Surrey.)

1278

New Centrifugal Fan

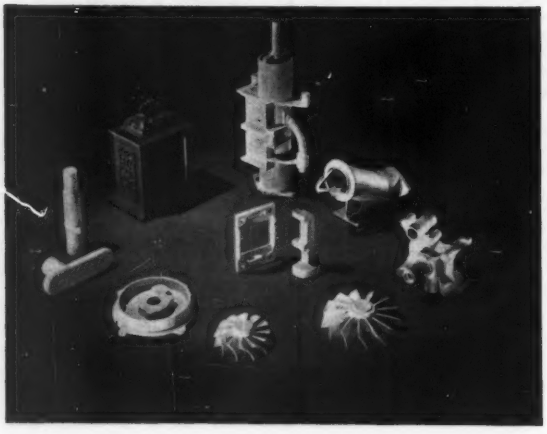
A maximum efficiency of over 90% is claimed for a new Matthews and Yates centrifugal fan arranged for direct coupling or V-rope drive, and the sizes available range from 20 in. to 10 ft inlet diameter. Fabricated construction is used throughout, with a spun inlet cone, and ball or roller bearings are fitted. Casings can be supplied for either left- or right-hand rotation, and with any of the eight standard discharge positions. For very large volumes, or limited headroom, double inlets can be provided. The fans are particularly suitable for air conditioning and ventilating systems where large volumes of air are required at high w.g. values.

(Matthews and Yates, Ltd., Cyclone Works, Swinton, Manchester.)

1279

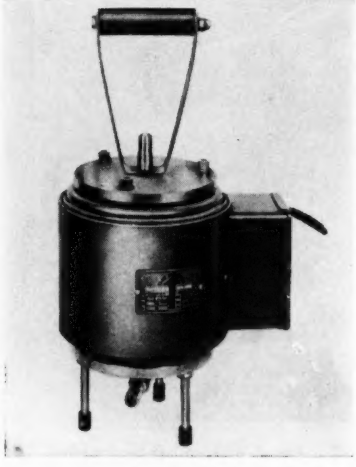
Portable Canned Pump

A portable leakproof pump, the El-10 has been developed in the U.S.A. for transferring corrosive liquids and solvents, and utilizes a stainless steel canning for the motor, and a magnetic coupling, to eleminate gland and alignment problems. With water, the maximum flow is 20 gal/min against 25 ft head; liquids up to a specific gravity



Left: Some typical brass and aluminium investment castings by Smiths.

Right: The Sethco portable canned pump for corrosive liquids.



of 1.5 can be handled. The maximum working pressure is 150 p.s.i., and the standard motor with class A insulation is suitable for fluid temperatures up to 210°F, although Class H insulation can be supplied for service up to 350°F. The motor is ¼ h.p.

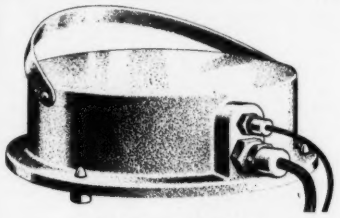
Vertically mounted on stainless steel legs, the overall dimensions are 17 in. high by 6½ in. motor diameter, and the weight is 25 lb. A stainless steel carrying handle is provided.

(Sethco Manufacturing Corp., 2284 Babylon Turnpike, Merrick, Long Island, N.Y.)

1280

Hotplates for "Hot" Cells

Ease of decontamination, positive location, and rapid handling with remote equipment are the main features of a hotplate specifically intended for active laboratory work. Originally designed for the curing of specimen mounts for irradiated uranium in the Dounreay "caves," decontamination is facilitated by the smooth stainless steel



The "Dounreay" hotplate.

casing. For accurate positioning in the cell, the hotplate is provided with three holes in the base flange, which fit over conical-end studs either welded or bolted to the bench, and the unit can be rapidly removed by a manipulator, by means of the swinging lifting handle provided.

Internal insulation is arranged so that the heating is restricted to the top surface, and not transferred to the bench, and a built-in thermocouple gives direct indication of surface temperature. A wide range of variations on the basic design is possible, including on-off, multi-heat, or Variac control.

(Spembly, Ltd., Nuclear Energy Division, New Road Avenue, Chatham, Kent.)

1281

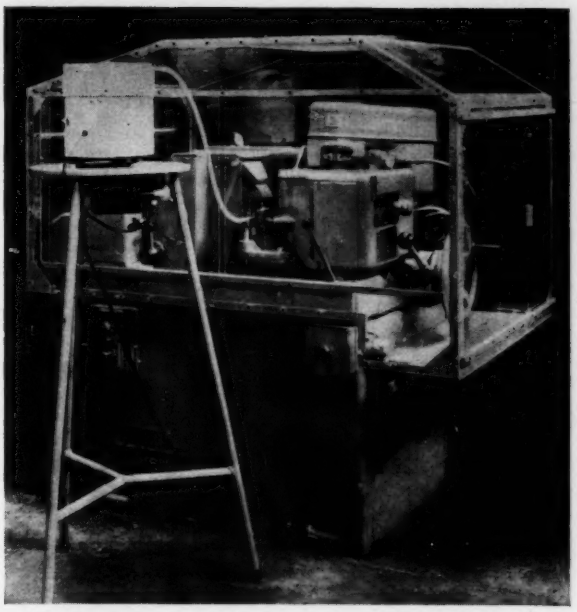
"Continuous Tiling"

While ceramic tiles have always been regarded as the ideal wall finish for resisting dirt and chemical contamination, the joints between them often present a problem. Correnda, a new plastics-bonded wall surface, while not as hard as a ceramic tile, eliminates joints entirely, and presents a smooth continuous surface, said to have excellent resistance to chemicals, detergents, disinfectants, solvents, fresh or salt water (hot or cold); to form a water vapour barrier, and to stand up well to impact and abrasion. It would appear to have desirable properties for "clean" rooms, and for situations where rapid decontamination might be necessary. Normally applied in a total thickness of about ¼ in., it adheres well to normal building materials including asbestos board and hardboard, wood and quarry tiles, as well as to cement, brick and plaster surfaces. The finish is normally glossy, to a wide range of B.S. 2660 colours; matt or special finishes can be supplied if desired.

(Corrosion, Ltd., 16 Gloucester Place, Portman Square, London, W.1.)

1282

Enclosed type Wickman - Scrivener centreless grinder for radioactive materials.



Enclosed Grinding for Pellet Production

The toxic nature of many nuclear materials (apart from any radioactive properties that may have to be considered) requires a degree of dust protection that cannot be obtained with certain machines by ordinary methods. Centreless grinding by its very nature is one of the more difficult processes, and our illustration shows a Wickman - Scrivener centreless grinder designed for these conditions. Complete protection is obtained by total enclosure within a hood of transparent plastics, doors being provided to give access to the machine controls when desired. The work is fed from a small vibratory hopper immediately in front of the machine. As shown, the machine was set up for the grinding of uranium oxide slugs to the fine tolerances necessary, its output being several thousand pieces per hour.

(Arthur Scrivener, Ltd., Tyburn Road, Birmingham, 24.)

1283

CATALOGUES

"Isomantle" industrial electric surface heaters for vessels, pipe lines, valves, instruments and drums, are described in a new brochure received from **Isopad, Ltd.** (Barnet By-pass, Borehamwood, Herts.)

"Products of the Rare Earth Group" is the title of a new publication from **Johnson, Matthey and Co., Ltd.** Sixteen metals are available as ingot or rod, and lanthanum, cerium, neodymium, praseodymium, yttrium and gadolinium have been successfully extruded and drawn into fine wire. (73-83 Hatton Garden, London, E.C.1.)

Leaflet P1/59, received from **Polypenco, Ltd.**, gives brief details of properties and applications of the engineering plastics produced and stocked. Nylon, nylatron, P.T.F.E., and cross-linked polystyrene are amongst those listed. (68-70 Tewin Road, Welwyn Garden City, Herts.)

A leaflet from **IEC-Sieger, Ltd.**, describes their electronic detector for explosive gases. (39 Parliament Street, London, S.W.1.)

A new Sifbronze price list, just issued by the **Suffolk Iron Foundry (1920), Ltd.**, includes two new gas cutting machines, as well as several new varieties of Sifbronze rods. (Sifbronze Works, Stowmarket, Suffolk.)

Jeltek, Ltd., have issued a new leaflet on waterproof clothing made from "Hydex" nylon-based P.V.C. coated fabric. (Green Lane, Hounslow, Middlesex.)

"A Service to Industry" is the title of a 56-page brochure produced by **Ashmore, Benson, Pease and Co., Ltd.**, and illustrating all phases of the design, manufacture and erection of all types of heavy engineering plant. (39 Victoria Street, London, S.W.1.)

A brochure, PE1259, from **P.G. Engineering, Ltd.** (a member of the Power-Gas Group) is entitled "Project and Equipment Engineering" and describes briefly, in English, French, Spanish and German, the facilities available, in the various divisions, for the design, supply, and erection of heavy plant in the chemical, petroleum, gas and nuclear industries. (39 Victoria St., London, S.W.1.)

Catalogue V-599 from **Claude Lyons, Ltd.**, lists "Variac" continuously adjustable auto-transformer units of all types, including ganged assemblies and portable units. A further list, S-592, lists automatic voltage regulators and stabilizers. (Valley Works, Ware Road, Hoddesdon, Herts.)

Fire-fighting equipment of all types, including dry and wet types of extinguishers, is described in a 94-page brochure issued by **Nu-Swift, Ltd.** (Elland, Yorkshire.)

Edwards High Vacuum, Ltd., have issued a new publication covering "Speedivac" equipment for vacuum coating devoted to a variety of technical applications ranging from lens blooming to tissue coating for capacitors. (Manor Royal, Crawley, Sussex.)

Motors for cranes, hoists and lifts are described in a new catalogue, ML 88 received from **Lancashire Dynamo and Crypto, Ltd.** (Trafford Park, Manchester 17.)

Armstrong hydraulic actuator units are described in a publication received from **Armstrong Patents Co., Ltd.** In addition to describing the types and sizes of actuator available, typical applications, hints on selection, and a range of stock auxiliary components are included. (Beverley, Yorkshire.)

"Molybdenum Disulphide in Action" is a booklet recently issued by **K. S. Paul (Molybdenum Disulphide), Ltd.**, containing some 30 pp. of extracts from "experience" reports from all branches of industry where this material has assisted in difficult lubrication problems. (Angel Road, London, N.18.)

Patents Reviewed

These abstracts have been made from British Patent Specifications, complete copies of which can be obtained from the Patent Office, 25 Southampton Street, London, W.C.2, at 3s. 6d. each (including postage).

B.P. 814,521. Production of uranium metal masses. A. E. Williams. To: U.K. Atomic Energy Authority.

Uranium masses are extruded through a die of fine-grained graphite of high tensile strength (Morgan EY 9062) with a high internal finish. The temperature should be within the gamma range of the metal (980 to 1,050°C), the pressure may be up to 4,000 p.s.i., die and uranium being in an inert atmosphere. The entry cone of the extrusion die has preferably an angle of 120°.

B.P. 814,996. Apparatus for handling nuclear reactor fuel elements. R. S. Challender, H. C. Knights. To: U.K. Atomic Energy Authority.

This refers to a press in which the fuel element is pushed through a die to cut away the sheath. Two retractable struts, hydraulically operated by rams and fitted with rollers, prevent bowing of the element during the initial cut of the die. The operation is carried out under water so that the operators are shielded from dangerous radiations but able to watch the process.

B.P. 815,096. Heat exchange devices. To: "Licencia" Találmányokat Ertékesitö Vállalat (Hungary).

This heat exchanger is particularly intended for the exchange of heat between two flowing media having heat transmission coefficients widely differing from one another. It consists of tubes with ribs at right angles to the longitudinal axes having separate distance pieces which are of good heat-conducting material, and bear both against the ribs and along their whole length against the tubes. For making the exchanger, the pile of ribs and distance pieces around the tubes is subjected to a pressure amounting to 80% of the elastic limit of the material of pieces and ribs, then a mandrel is passed through the tube to expand the tube to bear closely against the distance pieces.

B.P. 815,098. Process for the recovery of heavy hydrogen and heavy water. To: Stamicarbon N.V. (Netherlands).

The heat economy of a process in which heavy water is obtained by oxidation of deuterium recovered from water in a cyclic catalytic exchange system is improved by a two-step compression of the gaseous deuterium-poor hydrogen discharged from the top of the hydrogen rectification column.

B.P. 815,114. Cooling of fluids. L. R. Blake. To: British Thomson-Houston Co., Ltd.

The device is mainly intended for testing the suitability of metals for use in the manufacture of pipes for carrying liquid metals, e.g., cooling liquid bismuth with water. Two ducts are separated by a wall whose thickness is dependent on the heat transfer length of the ducts and a contemplated rate of heat extraction to give a thermal resistance for providing a temperature drop through the wall. This should be at least as great as the difference between the average temperature of the liquid metal over the heat transfer length and the maximum temperature allowable for the cooling fluid.

B.P. 815,469. Process for the production of shaped articles. To: Siemens-Planiawerke A.G. für Kohlenfabrikate (Austria).

Articles, of high resistance to heat and scaling, are made from powdered silicides and/or borides of the transition group elements of the 4th and 6th group in the Periodic System which have high melting points and good electrical conductivity. The powders are worked up into a paste with a liquid hydrolysable silicic acid ester, and shaped, and then subjected to hydrolysis, drying and sintering treatment. An intermediate mechanical working is possible. The articles may be employed where high thermal or electrical conductivity is required, such as tubes for molten metals, and also for the formation of thin non-scaling layers on metallic and non-metallic materials.

B.P. 815,515/516. Remote control manipulator. D. G. Jelatis (U.S.A.).

The arrangement of the counterweights balancing the movements of master arm and slave arm with respect to each other is such that one counterweight for the slave arm is located adjacent the connection of the master arm and support, but is connected with the slave arm so as to move with this arm when this arm is angularly adjusted with respect to the master arm. The counterweights for both arms are so arranged that the portion of the master arm projecting above the horizontal support is kept to a minimum (815,515). Interconnections are adjustable to vary the angular relationship between the arms (815,516).

B.P. 815,539. Voltage measuring circuits. M. O. Deighton. To: U.K. Atomic Energy Authority.

The amplitude of voltage pulses of short duration is measured by causing the incoming pulse to charge a capacitor to the peak voltage of the pulse. This voltage is stored across the capacitor while its amplitude is compared with a known voltage. Two circuits are used, one to charge the capacitor the other one to find when the voltage across the capacitor is equal to the known voltage. The use of one circuit only, operating in two different ways, would have the advantage of reducing errors in measurement. In previous arrangements they may occur in both circuits (e.g. through variations in contact potentials causing voltage drifts) hence the use of a multi-channel pulse amplitude analyser in which the width of each channel must be much greater than the possible drift. The new circuit is composed of an amplifier, a feedback connection for the amplifier, a switch for changing the sign of the feedback, and a capacitor. When the feedback is switched to negative the amplifier charges the capacitor to the peak voltage of an input pulse; when the feedback is then switched to positive the amplifier detects when the voltage on the capacitor has been reduced in a controlled manner to its value before the arrival of the pulse.

B.P. 815,923 Rotary apparatus. V. H. Brix. To: U.K. Atomic Energy Authority.

In compressors, stirrers and such apparatus there exists the problem of sealing the shaft driving the working member at the point where it penetrates the casing. Usually a squirrel-cage motor drives the impeller and the feeding of a barrier of lubricating gas to the sleeve journal bearing in a partition between motor and impeller portion can solve the problem.

B.P. 816,124. Fuel elements. L. M. Wyatt. To: U.K. Atomic Energy Authority.

The protective can of a cylindrical fuel element of a gas-cooled reactor is fitted with longitudinal fins and one or more helical fins extending radially beyond the longitudinal fins having slots at the intersections with these fins. The element may be supported in a graphite sleeve and the helical fins may also be of graphite and integral with the sleeve. This arrangement of fins limits adverse effects caused by deformation of the element.

B.P. 816,148. Remote control system. J. W. Smith. To: Collins Radio Co.

Refers to systems employing trinary codes and conducting wires between the remote controlled positions and the local control position. Each coding selection or each connecting wire carries a trinary code of various combinations of three different potentials or voltages. By combining any three of these wires with a ground return wire the code combinations which may be utilized are 3^n, where n is the number of connecting wires between the control and the control units. Prior systems could only control 2^n positions on three wires and a ground return.

B.P. 816,235. Shields for protection against neutrons. J. Duchêne. To: Commissariat à l'Energie Atomique (France).

Boron or cadmium (neutron absorbing material) powder in a binder of thermoplastic (vinyl) resin as material for flexible shields, gloves, overalls, anti-neutron suits, etc., to protect workers during nuclear physics experimentation or during work in the vicinity of nuclear reactors. Cadmium is not quite suitable for the protection of persons because it emits gamma rays under the effect of neutron absorption. Boron may also emit alpha particles but these are easily stopped, even by ordinary clothes. For satisfactory flexibility, the proportion of neutron absorbing material in the binder should be small (10%).

B.P. 816,919. Manufacture of clad fuel element. To: Atomic Energy of Canada Ltd. (U.S.A.).

The usual welding operation for sealing the ends of the aluminium sheath around the fuel rods or bars of uranium is a manual helium shielded arc method of welding using a tungsten electrode and an aluminium filler rod. The required perfect weld (to prevent leakage or porosity) depends to a great extent on the skill of the worker. The detection of microscopic porosity is difficult and the test employing high pressure and temperature may lead to destruction of the uranium fuel core. The difficulties can be overcome by the use of a pressure welding method. The assembly of fuel bar and aluminium sheath has an aluminium plug inserted into the end of the sheath, flush with the ends, and is clamped between dies which support the sides and leave only the end surfaces exposed. Plug and adjacent sheath portion are then heated to 800°F (or higher, but less than the melting point of aluminium) and subjected to a ram pressure of about 30,000 p.s.i. This results in physical bonding of the two pieces although the temperature remains below the melting point of aluminium.